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THE CAUSE AND PREVENTION OF DECAY IN TEETH

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THE CAUSE AND PREVENTION OF DECAY IN TEETH

AN INVESTIGATION INTO THE CAUSES OF THE PREVALENCE OF DENTAL CARIES; TO WHICH ARE APPENDED SOME SUGGESTIONS ON ITS PREVENTION

BY

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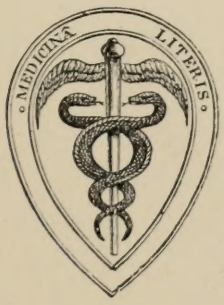

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SECOND EDITION

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PREFACE TO THE SECOND EDITION

The Second Edition is simply a reprint of the First, together with the record of an experiment, originally published in the *Journal of the British Dental Association*, entitled "Experimental Demonstration of the Cause of the Early Decay of Teeth."

J. SIM WALLACE.

30A Wimpole Street, W.

June 1902.

PRESS OPINIONS ON FIRST EDITION

"We believe the conclusions are fair, and the day is not far distant when the dental world will come to believe them as he believes them. We believe no progressive, up-to-date Practitioner of Dentistry ought to be without the book, to at least get the measure of himself by it, or to model his views upon it."

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"MR. WALLACE ably champions his own views, and the work has many points to stimulate thought; we can recommend its perusal to our readers."—*Dental Record.*

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PREFACE

Under the title of "The Etiology of Dental Caries," I published a series of articles in the *Journal of the British Dental Association*, which I am now publishing in book form, together with an introduction and chapter on the Prevention of Dental Caries.

I do so in order that the views which I have put forward may gain further recognition, and in the hope that the conclusions arrived at may form a rational basis for the prevention of this most prevalent and painful disease.

J. SIM WALLACE.

April 1900.

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INTRODUCTION.

The etiology of dental caries is a subject which has occupied the attention of physicians since the time of Galen, and fortunately, especially in recent years, much progress has been made in its elucidation. At the present day the pathology of the disease is well known, and its *direct* or *exciting* cause is all but universally recognised to be chemico-parasitical. With regard to the direct causation of the disease, therefore, I need say but little. I intend to direct attention to the causes or conditions which lead up to the direct or exciting cause, and to try to account for its extraordinary and increasing prevalence.

During the last decade the importance of arriving at a correct solution of the causes of the prevalence of this disease has been widely recognised, and has brought into existence many ingenious theories, none of which, however, seem to be gaining the general assent of those interested in the subject.

Although it has taken several years' investigation for me to arrive at the explanation which I am now about to advance, I believe its simplicity and its easy verification will commend it, if not wholly, at least in part. Never-

theless, I am quite aware that but few will for a time admit its truth, for though, as far as I know, it is in strict accord with current biological principles and accumulated facts, it is admittedly rather at variance with the currently accepted views among dental surgeons and medical practitioners.

CHAPTER I.

DENTAL CARIES AND ITS CAUSATION IN GENERAL.

There is fortunately much unity of opinion as to the nature of caries, and the following definition by Dr. Miller sums up what is currently accepted. He says, "Dental decay is a chemico-parasitical process consisting of two distinctly marked stages, decalcification or softening of the tissue, and dissolution of the softened residue. In the case of enamel, however, the second stage is practically wanting."*

Mr. Tomes makes the following summary of the direct or immediate causation of the disease: "That caries is an effect of external causes, in which the vital forces of the individual play no part.

"That it is due primarily to the solvent action of acids generated by fermentations occurring in the mouth, micro-organisms playing no small part in the causation of those fermentations.

"That once a breach being made by decalcification, others, or it may be the same organisms, take an active share in the further disintegration, partly by a peptonising action upon the organic basis of the tooth, and partly

* Miller, "Micro-organisms of the Human Mouth," p. 205.

perhaps by boring through and breaking up the softened dentine." *

Bearing in mind what caries is, we may next proceed to consider the conditions under which it takes place.

A variable number of micro-organisms are always present in the mouth, which, being a moist warm chamber richly supplied with food, might almost be compared to a well-devised incubator in which the micro-organisms multiply. At some places—*e.g.*, in the hollows of, and spaces between, the teeth—these micro-organisms are liable to be present in considerable numbers, and in these places too a certain amount of the food which was intended for the stomach is liable to lodge, together with epithelial cells, salivary mucus, and *débris* from various sources. When food and micro-organisms are left together in the mouth fermentation is set up, the numerous products of which are given rise to. The products of the oral micro-organisms vary both with the kinds of organisms and with the nutritive media in which they live. In general, if they live in an albuminous medium the products are those of putrefaction, and give rise to an alkaline reaction. In a saccharine, amylaceous, or mixed medium, acid products are the result. When acid fermentation takes place and a certain percentage of acid is formed in the medium, the further production of acid is retarded and ultimately stopped when the percentage of acid reaches about ·75.†

* Tomes, J. and C. S., "Dental Surgery," fourth edition, p. 255.

† Miller, "Micro-organisms of the Human Mouth," p. 14.

Although the products of the fermentation caused by micro-organisms are numerous and diversified, our chief consideration at present is with regard to the generation of acid, for although the various products of fermentation affect the gums and soft tissues of the mouth, and under certain conditions of depressed vitality may give rise to diseases, local and general, I intend to limit my remarks at present to those products which have a solvent action on the teeth.

Attention must be drawn to the action of the micro-organisms upon the various food-stuffs which are consumed by man. (1) *Albuminous food-stuffs or proteids.* The action of the mouth bacteria upon these is such as to give rise to the products of putrefaction with an alkaline reaction. They have consequently no solvent action on the teeth, and, indeed, neutralise to a certain extent the acids with which they may come in contact. (2) *Fats.* The action of the mouth bacteria upon fats, as far as is known, is practically nil. (3) *Carbo-hydrates* (starch and sugar). The result of the chemical decomposition by the micro-organisms of the mouth on this group of food-stuffs is the production of acids, chiefly lactic, and various other by-products which act but slightly and indirectly upon the enamel. They will be referred to later. The action of lactic acid is well known. It dissolves the mineral matter of the enamel and dentine whenever it reaches a certain degree of concentration. All enamel is subject to its decalcifying action when it reaches a certain strength. It may be assumed that the rapidity of its action may be greater in badly formed enamel, though

no definite experiments have as yet shown that badly formed enamel is more rapidly dissolved than that which is well formed. From a chemical point of view, the mineral matters consumed as food have no effect upon the teeth.

That it is the carbo-hydrates in certain forms which give rise to caries of teeth receives support not only from the facts revealed directly, and from experiments on fermentation of those substances under conditions similar to those which prevail in the mouth, and from observations and experiments in the mouth, but also from observations which show that races which subsist largely on proteids and fats are peculiarly free from caries, *e.g.*, Esquimaux, Maoris, Icelanders.* I have also found among my own patients that those who like meat, fish, and fat in preference to carbo-hydrates almost invariably have relatively good teeth, while those who are more addicted to sugary and starchy foods are, as a rule, predisposed to rapid and extensive caries. (This is a general statement, and other causes and modifying conditions will be referred to later.)

Caries is invariably initiated by the acid formed by the action of micro-organisms upon the carbo-hydrates which lodge after each meal in crevices and spaces between the teeth, and is continued in similar manner, the decalcified part acting as a more perfect receptacle for carbo-hydrates and micro-organisms. The micro-organisms when in the decalcified dentine also give rise to the destruction of its

* Mummery, *Transactions of the Odontological Society*, New Series, vol. ii. p. 7.

organic basis. The rate of the destruction of the tooth substance varies principally with the supply of carbohydrates to the micro-organisms in the carious cavity. If the orifice of the cavity is such that the supply of carbohydrates is but small, the carious action is slow, and if, for example, the supply should be practically cut off, as by the extraction of a neighbouring tooth whose position previous to extraction was such as secured a regular supply of carbohydrates, the decay will cease altogether. There are other circumstances which exercise an influence on the rapidity of caries, such as the acidity or alkalinity of the saliva, the perfection of the calcification of the teeth, &c., but these are of little importance.

The several conditions which predispose to caries may now be considered.

Firstly, the physical properties of the food-stuffs are of considerable importance. Certain food-stuffs, as a rule, on account of their physical properties, lodge about the mouth, others do not. This may be easily seen by eating a biscuit or a piece of cake and observing how many particles lodge in crevices, while fibrous food-stuffs, *e.g.*, stale bread, fish or meat are not so liable to lodge. This statement is made with a reservation, for in many mouths where the teeth have taken up abnormal positions, and especially when they have been imperfectly filled, teeth are particularly liable to catch these fibrous food-stuffs. As regards the common sites of caries in molars, meat, fish and fibrous matter generally are less liable to lodge on the crown than baked foods, especially those which are "short." I have made some six hundred experiments to endeavour to find

the food-stuffs which are more apt to lodge, but I do not care to place any too definite stress on the results, as the crevices examined were somewhat abnormal, inasmuch as they had been filled, and so did not represent the normal shape of the teeth. However, the experiments show that cake, biscuits, bread, especially toasted bread, are very liable to lodge from one meal to another, while raw vegetables, fruit, meat, fish, were by no means so apt to remain. There was one place, however, the crevice formed by the neck of the lower wisdom tooth, the edge of the gum and the fold of mucous membrane of the cheek, which was more liable to retain fish and meat. This position is, however, compared with the crowns of molars, a relatively infrequent seat of caries. The reasons for this will be more fully accounted for if we consider the chemical composition of food.

There are some foods which from their physical properties appear to clean the teeth, while others tend to leave a coating over them. Soft, non-fibrous foods which do not require to be chewed, especially those with much sugar, leave the teeth with a coating in those parts which are least rubbed by the tongue and cheeks. This is easily noticed by observing the state of the teeth after eating, *e.g.*, chocolate or other kinds of soft sweets, or even milk puddings. I have not been able to arrive at a conclusion as to whether the viscidity of the saliva and oral mucus tends to augment this: possibly it does.

There are some races which eat largely of fish from certain rivers which contain much fine sand; the effect of this on the teeth is to wear down the crowns, and yet these

races are practically free from caries; for instance, some North American Indians.* So also races which subsist largely on roots, which, as they prepare them, are not only fibrous, but gritty from the earth which they contain, have teeth practically free from caries; for example, Kaffirs.* It is noteworthy, too, that when sugar is obtained by sucking and chewing the sugar-cane, no harm seems to be done to the teeth, probably on account of the cleansing action of the fibrous part of the sugar-cane, and on account of the sugar being free from mixture with matter which tends to lodge in the crevices of the teeth.

The physical properties of fats in acting as lubricants to the foods taken with them are probably of some importance. I have made numerous observations which seem to me to indicate that the relative freedom from caries among people who eat much fat is out of all proportion to what one might expect if one considered fat as neutral in its action on the teeth. Nor do I think that we can account for this freedom from caries in fat-eaters by the fact that these people may eat relatively less carbohydrates.

That eating of fat is not conducive to caries, if it is not positively inimical to it, has been proved by experiment by Dr. Miller,† independent of any observations I have made, and it may further be mentioned that races which subsist largely on fats are peculiarly exempt from caries, *e.g.*,

* Mummery, *Transactions of the Odontological Society*, New Series, vol. ii. p. 7.

† Miller, "Micro-organisms of the Human Mouth," p. 209.

Icelanders and Esquimaux,* &c., and lastly, generally speaking, caries is less frequent and less rapid in people after the age when they begin to eat more fats.

The physical and chemical properties of the secretions of the mouth probably exercise some influence on the causation of caries. The saliva, though normally faintly alkaline, is frequently neutral or slightly acid, and sometimes viscid.

This viscidity and chemical reaction may to a certain extent be due to the by-products of the micro-organisms which are fed and incubated in the mouth. In some cases, for example in fevers, the influence of the buccal secretions and general state of the mouth is marked, and much harm may result to the teeth, but this is perhaps principally due to the kind of food taken during such illness rather than to the peculiarity of the secretions; one of the most certain methods of inducing caries being to sip constantly at liquid foods, and to dispense with the use of the tooth-brush. The presence of micro-organisms in numbers is also a condition that favours caries. It has been shown that, when carbo-hydrates are lodged in a dirty mouth, the rapidity with which acid is produced, and also the quantity, are very much greater than if the mouth had been previously cleansed with tooth-pick, tooth-brush, &c. On the other hand, certain food-stuffs which have been sterilised by boiling are much less liable to give rise to acid than when unsterilised. Thus milk which has been boiled may remain in the mouth for many

* Mummery, *Transactions of the Odontological Society*, New Series, vol. ii. p. 7.

hours without giving rise to much acid, while unboiled milk rapidly develops acid fermentation when lodged in the mouth.

The length of time which elapses between meals seems to have some influence on the initiation and rapidity of decay. Millers as a rule have carious teeth, which is probably due to the continual breathing in of flour dust, &c.; so, too, have cooks and confectioners, who frequently taste the foods they are preparing.

Some kinds of meals are undoubtedly more harmful than others. Afternoon tea is as a rule very injurious to the teeth. The infusion of tea is in itself harmless, but the milk, the sugar, and the bread and cakes are all very harmful, especially when taken with a liquid which enables the consumer to take the meal with very little exercise to the jaws. After such a meal as this the mouth is left in a very excellent state for the development of acid, and for the multiplication of the millions of micro-organisms in the mouth. All sloppy meals, such as are often prescribed for invalids, are seen to leave the mouth very much more dirty than meals which require much chewing. Liquids, when taken with food, are harmful when taken to soften the food, but when taken in quantity, especially after meals, are of considerable benefit in checking the formation of acid, as they mechanically cleanse the mouth and dissolve some of the carbo-hydrates which would otherwise have lodged in the mouth.

The microscopical and chemical structure and composition of the teeth is often said to be a predisposing cause of caries, but there is little to support this theory. Gene-

rally speaking, the molar teeth, which are most highly calcified, are most liable to decay. (Black,* Tomes,† Leon Williams.‡)

The idea prevalent that in localities where there is little lime salts in the water the teeth are imperfectly calcified, and more liable to caries on that account, has no basis on statistical data. The degree of calcification of a tooth in no way influences the production of acids by micro-organisms and carbo-hydrates. After caries has started, however, an ill-calcified tooth may probably be slightly more rapidly decayed than one which is more perfectly calcified, as the acid-forming micro-organisms have a more easy prey.

There are several conditions which favour the lodgment of food and micro-organisms about the teeth. The natural crevices of the teeth themselves are liable to retain many of the food-stuffs which are commonly consumed at the present day. If a mouth be examined in which the teeth have all been filled at regular short intervals by a dentist, it will be readily seen how faithfully caries originates and progresses in these crevices. It will be noticed in examining such a mouth that the fillings are invariably in such places as are protected from friction by the tongue, by the cheeks, or by the opposing teeth. Thus the rounded surfaces next the tongue or cheeks, or the cusps which occlude with opposing teeth, are practically never the seat of caries, but the crevices between the cusps, or the crevices or pits on

* Black, "Dental Cosmos," 1895.

† Tomes, *Transactions of the Odontological Society*, New Series, vol. xxviii. pp. 118 *et seq.*

‡ Williams, "Dental Cosmos," 1897.

the surfaces of the teeth, are invariably the sites of the fillings. Not only is this so, but the caries extends at first as a rule in the direction in which the crevice runs. Thus in the lower molar teeth the filling should be shaped like a cross +, the dentist thereby not only removing all the decayed matter, but also filling in the whole of the crevice with a filling material which is not acted upon by the food and micro-organisms which may lodge. If the fillings are not made to fill the crevices, but only a circular filling made when the caries is removed by the dentist, the result is generally that in course of time the tooth becomes carious in the crevice at the sides of the filling, and decay proceeds till the filling or the tooth is lost.

So, too, fillings are frequently seen on the approximal surfaces between the front teeth, and a broad smile or a laugh by a person with such fillings is sufficient to show the food which lodges in these situations after most meals. If attention is now drawn to the lower front teeth it will very generally be found that these are not filled and do not require filling, because, on account of their shape and the arrangement of the gum and the action of the tongue in dislodging matter between the teeth, or causing a current of saliva to pass between them, food does not lodge there and undergo acid fermentation. This fact is the more remarkable as these teeth are not so highly calcified as the molars, and should, according to most of the current theories on the causes of caries, be the most liable to be attacked. When the crevices or pits in teeth are abnormally deep the tendency for food-stuffs and micro-organisms to collect is augmented, and the liability to caries is greater.

Teeth are, however, fortunately seldom what may be called abnormal in shape, so that this is only occasionally a predisposing cause of caries. The arrangement of the teeth among themselves is, however, a very general cause of the lodgment of food about the teeth. A normal set of teeth is so arranged that food, at least coarse food, is but little liable to lodge, but unfortunately few people have a regular set of teeth. When the normal relation of one tooth to another is broken it becomes a task of very much greater difficulty to prevent the lodging of food, especially between the teeth, and all the precautions which will be mentioned later for the prevention of caries must be carried out much more thoroughly than is necessary when dealing with a regular set of teeth. It happens that to a great extent the conditions which are favourable to the development of caries are similar to those which favour irregularity. In general, when the temporary teeth are well used by properly masticating reasonably coarse and fibrous foods, they remain sound till they are naturally shed. Moreover, when the teeth are honestly put to perform their natural function, the jaws grow, and so give sufficient room for the taking up of the normal positions of the permanent teeth.

There is an unfortunate belief which seems to be current that the jaw of man is not normally large enough for the teeth; that in fact, in the transition from the large-jawed savage to the small-jawed civilised man, the jaw has diminished in size more rapidly than have the teeth. This appears to be supported by the fact that the teeth of bull-dogs are crowded and large relative to the jaw. Of course in the case of dogs the effect of artificial selection is con-

fined to what is shown externally. In the case of man, however, even though a small-jawed individual may be presumed to be more beautiful and, *cæteris paribus*, more liable to be preserved and have offspring, equally, however, are small teeth regarded as beautiful, and might be supposed to be equal factors in sexual selection. This subject will be referred to more fully in chap. v.

The relative sizes of the teeth and jaws have little to do with æsthetic considerations, and indeed the wisdom tooth has diminished in size much more quickly than has the jaw. The principal reason for the want of growth of the jaw is the fact that it is not sufficiently used, and does not develop to its normal size. The crowns of teeth, however, being fully formed as regards size beneath the gum before they are functionally active, the size of the teeth is independent of the amount of use they are put to by the individual. Hence a quick transition from coarse food to soft food in one generation brings about a crowded and irregular set of teeth, and an accompanying amount of dental caries. The cause of the smallness of the jaws compared with the teeth may easily be shown to be due to the non-development of the jaw-bone through lack of the proper amount of work being thrown upon it and the tongue.

The exceedingly bad results of feeding children on soft foods after they have got their temporary teeth may be indicated by tracing what happens as a rule in these circumstances. A child gets its temporary teeth, and assuming even that they are not decayed, the teeth of the permanent set replace the incisors, then the bicuspids

displace the temporary molars, and the second molar coming into place presses forward the first molar, as the jaw has scarcely expanded enough to let it form and take its position. Then at the same time the canine, which forms deep in the jaw-bone, tries, as it were, to take up its normal position, but is crowded out. The result is an irregular set of teeth, and, the soft foods being continued, caries is started in some of the spaces where food is so very apt to lodge; one or more teeth become carious, and further tend to make the patient stop masticating his food and so cleansing his teeth in a natural manner. Two or three years probably elapse, during which the mouth is crammed with micro-organisms and liberally supplied with food for acid fermentation.

When such a course of events takes place we need hardly be surprised if a few of the teeth fall a prey to the acid developed. What usually takes place, however, is that the temporary molars are lost before their successors are ready to take their places, and so the first permanent molar slips still further forward. The space in the jaw available for the twenty front teeth is made still smaller, and the evil results are augmented.

The above is but a rough indication of a cause which leads indirectly to the irregular position of the teeth and consequent lodging of food and micro-organisms resulting in caries. As children of the same family are usually brought up on similar food, and their tastes are more or less alike, caries is commonly more pronounced in some families than in others, and as the initial causes are so remote and difficult to trace, there is a popular impression

that the tendency to caries is constitutional. Caries is also for similar reasons supposed to be hereditary, but strictly speaking it is not. It is invariably acquired from external influences, and is never inherent.

Another circumstance which gives rise to conditions favourable to the lodging of food is recession of the gums. When this takes place the space formed by the gum, the buccal side of the teeth, and the buccal mucous membrane is increased, and food is apt to lodge. The spaces between the teeth are also increased by the recession of the gums, and food is more liable to lodge here too. It is principally on this account that these are more commonly the sites of caries among adults, and less frequently in childhood and adolescence. The wearing of artificial dentures is also a frequent cause of caries by lodging food-stuffs and micro-organisms about the teeth. In this respect metal plates are more objectionable than vulcanite, inasmuch as they are never made to fit sufficiently closely to prevent the lodgment of some food, and are generally held in place by bands which clasp the teeth, and destroy them quickly or slowly according to the amount of food which accumulates about the bands. Vulcanite plates held up by metal bands are harmful in the same way, but may, however, be made to fit so accurately when worked from a plaster impression that bands are as a rule unnecessary.

Lastly, there are indirect causes which render the lodgment of food and consequent caries liable to occur. Many people are careless in the use of means to clean the teeth, using neither tooth-pick, brush, nor powder, either from ignorance, carelessness, or laziness. During many illnesses

the lassitude which they induce often gives rise to a certain amount of negligence which is not wholly natural to the patient. Hence during illness or pregnancy this cause acts more pronouncedly than at other times.

The prevalent erroneous beliefs that caries is hereditary, that it is constitutional, that it is due to civilisation, all tend to make people careless, and cause them to leave their teeth to fate, or at the best, to their dental surgeon. Fortunately caries is no more constitutional than small-pox or measles, no more hereditary than frost-bite, or tattoo-marks. All are the result of external causes. Nor is civilisation, strictly speaking, a cause of caries. But upon the subjects of heredity and civilisation I intend to dwell more fully in the following chapters.

CHAPTER II.

INFLUENCE OF HEREDITY.

There are many theories at present in vogue which attempt to elucidate the cause of the increased frequency of caries of the present day. Chief among these is the theory of the degeneracy of teeth. The belief in the inherent degeneracy of teeth has taken such a hold of many authors that they have gone still further, and advanced a theory to explain the cause of the supposed degeneracy.* A favourite explanation has been the theory of the inheritance of acquired characteristics; the belief that in the development of the body in infancy the over pressure of intellectual education has deprived the teeth of their due proportion of nutrition, has also had its advocates; and recently another theory, that the abnormal temperature of the food given to infants acts injuriously on the developing teeth, has been advocated by Mr. Cantlie in the attempt to explain this degeneracy in teeth.† The belief in the degeneracy of teeth due to the inheritance of acquired characteristics might be held by those few who still cling to the theory that acquired characteristics are

* Smale and Colyer, "Diseases and Injuries of the Teeth," Introduction, p. xii. and p. 146.

† Cantlie, *Brit. Med. Journ.*, Sept. 2, 1899, p. 512.

inherited, were it not for the fact that the injury produced on the teeth by caries is essentially a mutilation, caused chiefly by acid, and it is now many years since the idea that mutilations were transmitted was altogether abandoned.

With regard to the developmental theory, I shall take the liberty of quoting from a recent article in the *British Medical Journal* on the subject, by Mr. James Cantlie, M.B., F.R.C.S., with whom, in what I am about to quote, I quite agree. He says: "The developmental idea is a favourite theme; it is even seriously discussed by persons of respectable scientific attainments. The idea is, that in our quest after education, we are attracting a superfluity of blood to our brains and thereby starving our teeth and our jaws. A very pretty theory indeed, but it is not true."

Whether it is that dentists, in their endeavour to make an explanation of the increased prevalence of dental caries, have concentrated their attention on the teeth, and have been unable to look outside the teeth themselves for the causes of caries, or whether they have been confused by the loose use of the word degeneracy, I can hardly say. To say that the prevalence of caries is due to the defective constitution of the tooth is a convenient way to evade giving a scientific answer to the question. But it has yet to be discovered and proved that the constitution of the teeth of, say, the Icelanders in any way differs from that of the English, or in what respect the constitution of the teeth of the present day differs from that of our ancestors. Certainly the hygienic conditions of the English of to-day

compare favourably with those of our forefathers or of the Icelanders; and as a matter of fact, the teeth of the present day are as perfectly formed from a chemical and microscopical point of view as are the teeth of those races which are practically free from caries.

In considering this subject it is well to observe what is meant by degeneracy of teeth. In one sense the teeth of civilised peoples may be called degenerate, inasmuch as they are deteriorated by the ravages of caries; but this of course cannot be called a *cause* of caries, otherwise we should be calling caries the cause of caries. This error is only fallen into by a few writers on this subject, and the degeneracy in teeth is considered by most authorities to mean a structural defect in the constitution of the tooth which renders it liable to be attacked by the acids which the micro-organisms give rise to in the mouth. Structural defects do occur, and when they take the form of pits or crevices, certainly facilitate the lodgment of carbo-hydrates and micro-organisms, and so give rise to caries; but these structural defects occur amongst the uncivilised as frequently at least as among the civilised.

Mr. Tomes says, "It would really almost appear as though bad teeth were inherited with more certainty than good teeth."* This is apparently quite a general belief. The fact of the matter is that the teeth are inherently just as excellent in structure as they were generations before. Hereditary peculiarities, which may or may not favour the lodgment of food and micro-organisms, may be assumed to exist, but the reason for the increased preva-

* Tomes, "Dental Surgery," p. 253.

lence of caries is due to the fact that food-stuffs are gradually becoming more apt to lodge in the mouth on account of their physical properties being changed; all coarse, fibrous and gritty food-stuffs (which on being masticated cleanse the mouth) being gradually superseded by soft, fine, "short" and "sugar-coated" food-stuffs, which, on being squashed in the mouth, get jammed into all the crevices of the teeth to be worked into acid by the micro-organisms which are lying in wait for their appetising repast.

I wish now to deal more particularly with the subject of *heredity* in its relation to caries in teeth. Professor Weissman, who is perhaps the most generally accepted authority on heredity, makes the following definition: "By the term heredity is simply meant the well-known fact that living organisms are able to produce their like, and that the resemblance between a child and its parent, although never perfect, may nevertheless extend to the most minute details of construction and functions." * If we accept such a definition (which is true, whether we believe in Prof. Weissman's conclusion or not), then heredity refers to the fact of a certain *resemblance* of offspring to parent.

If we consider, as scientists do, that heredity is the potentiality of organisms or of their germ-plasm, by which certain peculiarities are repeated generation after generation, we cannot at the same time say that it is the potentiality of the germ-plasm by which peculiarities spring up in one generation which were wanting in pre-

* Weissmann, "Germ Plasm," p. 20.

vious generations. It is thus distinguished from spontaneous variation. Heredity therefore can in no way account for the *increased* amount of caries at the present day. As this point is of much importance and is generally overlooked, I shall repeat this truth in different language. Heredity refers to a fact, the fact of the *resemblance* of offspring to parents, though what many authors claim as caused by heredity is the supposed *difference* of the constitution of the teeth of the present generation from the constitution of the teeth of ancestors.

In speaking of the hereditary nature of disease, John Hunter says: "I do not know that we have an instance of observation which proves that the circumstance of a person's having had the disease renders him more liable to communicate that susceptibility to his offspring than if he had only the susceptibility for the disease without the action taking place. If it was a fact that the parents having simply had the disease in some degree entitled their offspring to it, the human species would soon become extinct in those places where such diseases arose; and if the parents having had the disease increased the susceptibility in the offspring, both smallpox and lues would have become incurable by this time. So that the immediate cause, whatever this may have been, does not, in consequence of its having had its full effect, either give, or even add to, the disposition for such action."* And the truth of Hunter's observations is borne out by the attitude of scientists at the present day.

Furthermore, it is generally admitted that the pre-

* Hunter's Works, Palmer's edition, p. 358.

disposition to certain diseases among different races is inversely proportional to the number of generations during which the disease has been prevalent. Thus, for example, malarial fever is less liable to afflict peoples who have for generations lived in malarious districts; and measles is a much more terrible disease to certain tribes where it has recently been introduced than it is among ourselves, where it has been prevalent for many generations.

There are two factors which influence the growth and development of organisms; one is *heredity*, the other *environment*. These factors are often confused. Let us take a simple analogy which will bring out what I wish to draw attention to. A chemist had a son who was also a chemist. The father frequently had stains on his fingers due to the falling of acid upon them. Likewise the son had frequently stains on his fingers from the same cause. We do not say that the stains were due to heredity or any inherent tendency, we say that they were due to the acid or to the environment in which the chemists worked. Nor do we say that the occupation which predisposed them to have stained fingers (viz., the fact of each being a chemist) was inherited. So, too, when speaking of the decalcification of the enamel by the acids produced by micro-organisms. The cause of the decalcification is due to the acid, and the predisposition to the presence of acid must be sought in the conditions which favour its presence and development. Only the other day I observed what appeared to me another instance of this confusion of heredity and environment. Dr. Black, while combating the theory that the predisposition to caries exists in the

teeth themselves, continuing, says: "I suppose the hereditary predisposition of certain families to caries has been so generally observed that it will not be questioned, and only needs mention. In the practical consideration of cases as they are presented to us when we have the care of families of children, the hereditary predisposition to caries is of the first importance." *

I think he has been misled by not observing that what he calls a hereditary predisposition is really an environmental one, otherwise he would hardly have advanced the theory that the predisposition to caries is due apparently to the hereditary character of the oral secretions. This belief has certainly as little to commend it as the one he combats, since the environment of the teeth is altered directly and indirectly by every food-stuff which enters the mouth, and the oral secretions are influenced by the foods directly and indirectly, by the micro-organisms directly and indirectly, by the odour of food, and even by the thought of it. I think any one will be able to produce the gelatinous coating he refers to as necessary for the initiation of caries by eating sweets, as mentioned in the last chapter.

We are certainly not justified in expecting a predisposition to the formation of acid to exist in the enamel, which is a wholly inorganic substance. We are therefore compelled to admit that the predisposition exists solely in the environment of the teeth. I have observed numerous cases, of some of which I have a written record taken when the teeth were either particularly ravaged by, or particularly free from, caries, and in no case have I found

* Black, "Dental Cosmos," September 1899, p. 829.

an instance where the food-stuffs which were usually consumed were not, as far as I could judge, sufficient to account for the freedom or otherwise from caries. And I am strongly of opinion that even the rapidity of the caries is almost solely due to the kinds of foods consumed, together with the other conditions already mentioned in the foregoing chapter, and not to any inherent defective structure of the tooth itself. It will probably have struck most dentists, and I have seen it commented upon in works on dental surgery, that honeycomb teeth, which are the most grossly defective that we ordinarily meet with, are not apparently prone to rapid decay.

With regard to the fact that caries is generally found to affect some families more than others, the principal cause of this is that the foods consumed are, allowing for individual tastes, generally the same, and the cleansing of teeth is neglected or otherwise, according to the habits of the parents. The fact that caries is often strongly marked in certain families has given rise to the supposition that there is a strongly marked inherited tendency, although all that is strongly marked is the similarity of the environment, or, in other words, of the conditions—chiefly dietetic —which prevail in certain families. This "inherited predisposition" is supposed to extend to whole races, and is apparently assumed to be due to defective developments. Again, I must point out that the environment of the teeth due to dietetic customs does produce a tendency to caries, but that environment is not inherited. It fortunately happens that most, if not all, races show plainly that it is not any inherited racial predisposition

which is the cause of caries. Thus, for example, in the Caucasian race, certain branches are peculiarly affected with caries, others are almost wholly exempt from the disease. The most interesting example of this occurs in the Teutonic branch. The English have very carious teeth, while in Icelanders caries is almost unknown. The American Indians show the same fact both in North and South America; some have practically no caries, whilst others, chiefly living in cities, have a considerable amount. So it is with the Mongols. The Chinese have carious teeth; the Samoyedes are practically free from it.

Professor Wedl says: "If it be true that geological and climatic conditions, and the means of subsistence which are connected with the same, have such a preponderating influence in respect of the frequency of caries, then it is impossible to explain the fact that foreigners belonging to different races, who are exposed to the same conditions with the native inhabitants, still retain the typical structure of their teeth as well as that of their bodies, and continue to furnish the proportion of dental caries peculiar to their race. This is found to be the case with the isolated Sclavonic races of Austria, and the descendants of the Celtic race in France."* Let us first discover if it be true that the foreigners belonging to different races are exposed to the same conditions as the native inhabitants. First, as regards the isolated Sclavonic races of Austria. It is one thing to live in the same country, and quite another to live under the same conditions. Thus on turning to the "Encyclopædia Britannica," we

* Wedl, "Pathologie der Zähne," p. 323.

read, "The population of Austria is made up of a number of distinct races, differing from each other in manners, customs, language and religion, and united together only by living under the same government."* From ethnographical details it appears that the Germanic peoples, generally speaking, centre round towns, unlike their Sclavonic neighbours,† hence these Germanic peoples are more subject to the influences of a "civilised" diet, living as they do where there is an interchange of food-stuffs, which are much refined.

As regards the Celtic race in France it is easy to show that the food-stuffs, and consequent environment of the teeth, are different from those of the rest of the population. One of the principal industries of Brittany is fishing. Fish is plentiful. "Agriculture is in general in a very backward condition." "Dairy produce forms a very important item in the food of the people." "Industrial pursuits, except in a few seaport towns, which are rather French than Breton, have hitherto received little attention. The Bretons are by nature conservative. They cling with almost equal attachment to their local customs and their religious superstitions."‡ Thus it will be seen that the customs of these Celts, even as regards diet, differ considerably from the customs as regards *cuisine* of the typical French. Moreover, ethnologically there is not a great gulf between the French generally and this more traditionally Celtic stock. The really great

* "Encyclopædia Britannica," ninth edition, vol. iii. p. 118.

† *Times* Atlas, Ethnographical Map of Austria-Hungary, p. 46.

‡ "Encyclopædia Britannica," ninth edition, vol. iv. p. 354.

gulf between them is principally linguistic, so that from this point of view the argument that the French have bad teeth, and the Bretons good teeth, must rather be taken as an argument that the difference as regards caries is not racial, but rather a difference due to dietetic customs.

As to Dr. Hitchcock's remark, on the other hand, that "as geological, climatic, and social conditions exercise a preponderant influence upon the growth and development of the various races, mentally as well as physically, it is evident that the development of the dental organs cannot fail to be controlled by the same causes. In this country, which is annually receiving large numbers of foreigners by immigration, the typical traces of race are usually effaced after the lapse of a generation or two, the descendants possessing all the peculiarities, and their teeth apparently being as liable to caries as the teeth of Americans generally;"* it is well known to biologists that these conditions do *not* exercise a *preponderant* influence on growth and development; besides Dr. Hitchcock's statement is absolutely contradicted by the negroes in his own country (America) who resemble the African negro in every physical and mental characteristic, while the whites are almost indistinguishable from the whites of Europe. On the whole, however, as regards dietetics, there is a considerable similarity in the customs of the blacks and whites of America, and a considerable amount of caries in both cases. As regards the whites more especially, the dietetic customs of the various peoples who emigrate to

* Wedl, "Pathologie der Zähne," translated by W. E. Boarman, with notes by T. B. Hitchcock, p. 401.

the United States gradually change with the changes in pecuniary circumstances in which the children more especially are placed; and also as soon as they forget the language of the nation from which they sprang, they lose the customs of their nationality. Thus in a generation or two, generally speaking, they adopt the dietetics and customs of the Americans, and have carious teeth accordingly. If the typical traces of racial characteristics were effaced after a generation or two, or even after a score of generations, due to geological, climatic and social conditions, the sciences of anthropology and ethnology would require to be reorganised. It is, in fact, the extreme tenacity of typical racial characteristics, quite independent of geological, climatic and social conditions, upon which both of these sciences are based.

To prove how mistaken Dr. Hitchcock's remark is, we find the English, in any quarter of the globe, retaining essentially the typical characteristics of their English origin (provided always there has been no intermarriage). Notwithstanding geological, climatic, and social conditions depending thereon, the Europeans of North America are as distinct from the North American Indians as the Europeans themselves. Intermarriage among other Europeans in America will certainly tend to obliterate the more minute racial differences. The mixture of Latin-American and Anglo-Saxon American probably does produce a somewhat different type from any to be found in other parts of the globe. But the point which I wish to insist upon is, that the people of America have caries to an amount much exceeding the average amount of the

various races who emigrated to the United States. It has not yet been shown that the development of the teeth has suffered structurally by the crossing of the races, and indeed instead of the crossing being a cause of degeneracy in the structure of the teeth, resulting in caries in America at the present day, it should rather be expected that there should be less caries in that country, as according to the laws of heredity when varieties of a species are crossed there is a tendency to reversion to ancestral type.

It appears to me that there is no other explanation of the excessive frequency of caries in the teeth of Americans than that which attributes it to the kind of diet to which they are addicted.

CHAPTER III.

CIVILISATION.

That the prevalence of caries among civilised people is greater than among savages is a well-established fact, and it is argued that civilisation is a predisposing cause of caries. This supposed cause is too indefinite for any practical purposes, and I shall endeavour to show that although caries is intimately connected with the advance of civilisation, the resulting caries is, as it were, an accident, and need not be a necessary consequence of civilisation.

In glancing over the history of the civilised from the time of their uncivilised forefathers, it is obvious that much of the advance has absolutely nothing to do with caries in teeth. I think it will be admitted, however, that if we direct our attention to the evolution of the means of obtaining food, and of the processes to which foods are subjected, the investigation may presumably be in a profitable direction.

In the early periods of man's existence there was little social cohesion, and each individual had to a great extent to concern himself with securing food, and, when he had the opportunity or inclination, with cooking it. It is known, however, that cookery was indulged in from very

early times. Even before the introduction of suitable utensils which could be used for boiling over a fire, it was to a certain extent managed by the introduction of hot stones into the liquid foods, which were collected in whatever utensils were most convenient for holding them. Methods were in use for roasting meat, fish, roots, nuts, &c., which, together with fruit, seemed to have supplied the needs of remote savages.

When we compare such a state of affairs with the various methods of securing food at the present day, and the elaborate machinery (flour mills, rice mills, sausage mills, sugar refineries, meat juice factories, &c.) by which many of the foods are refined, not to speak of the processes to which foods are subjected in our bakehouses, biscuit factories and kitchens, we see that there is some difference in the food of the present day from that in past ages. It may be said, however, that, after all, the foodstuffs have not essentially altered. We require proteids, carbo-hydrates, fats, water and mineral matter, much in the same proportion as our ancestors, and this is what we get. There is one change, however, which has gone on, and is at the present time going on, till it has reached a stage which is absolutely detrimental to the well-being of the teeth, stomach, alimentary tract and body generally. There is a gradual elimination of *all* the coarse, fibrous, inert and undissolved earthy matters which are present more or less in the food of savages. The teeth are no longer used and burnished by these natural tooth brushes and tooth powders, and the stomach and intestines no longer have their movement sufficiently stimulated by the

natural excitation of the food-stuffs. By many, the effects which should be secured by innutritious matter are secured by the daily use of aperients in order to keep the intestines in proper condition, and by as many the teeth are kept in a fairly good condition by an annual visit to the dentist. That there may be authoritative support for much of the above, I shall quote from Sir Henry Thompson's work on "Food and Feeding." Remarking on whole wheat meal bread he says: " . . . no portion of the husk of the grain should be removed from the wheat when ground, whether coarsely or finely, into meal. That a partial removal is systematically advocated by some as an improvement, is one of the numerous illustrations of the modern and almost universal craze which just now exists among food purveyors of almost every description, for eliminating all the inert or innutritious matter from the food we eat. This extraordinary care to employ nothing in our diet but matter which has nutritive value, that is, can be absorbed into the system, is founded upon want of elementary knowledge of the first principles of digestion. . . ."* And again, "It seems to me now to be almost overlooked that no proper action of the intestines can take place unless a very considerable quantity of inert matter is present in our daily food, existing as material which cannot be digested. . . . When there is a considerable proportion of this in the food the bowels can act daily and regularly, having a mass which they can transmit. When, on the other hand, the food is so 'nutritious' as to be almost entirely absorbed, there is

* Thompson, "Food and Feeding," tenth edition, p. 78.

very little solid matter to transmit, and the action of the bowels is therefore scanty, irregular and insufficient. This is, in fact, a very extensively recognisable cause of a great deal of the habitual constipation so prevalent among the middle classes at the present time."*

That a craze for eliminating the inert matter should be so universal when it is detrimental to the well-being of the body may well cause surprise. Why should the craving for the nutritious only have sprung up? The answer is simple. The nutritive instinct is the most primitive, the most fundamental, and the most ineradicable with which we are endowed.† Throughout the whole course of evolution, at least up to the advent of a moderately high standard of civilisation, this desire for the nutritious and aversion to the innutritious has been a beneficent instinct to all who possessed it, for during all that time, however strong was the desire for that which was nutritious, there was always too much of that inert and coarse matter which is now so necessary. It is unfortunate that this instinctive preference for soft nutritious foods exists in so marked a degree at the present day, when it is detrimental to a certain extent, and I fear it must remain yet, for multitudes of generations to come, a serious hindrance to the prevention of caries. Whether reason and the knowledge of what is the correct thing, together with the possible influence of fashion, based on physiological principles, which may spring up, will counterbalance the evil, time alone will tell. I need not point out in how many

* Thompson, "Food and Feeding," tenth edition, p. 88.

† Ribot, "Psychology of the Emotions," pp. 199 *et seq.*, and 432.

ways this preference for the succulent and nutritious must have been advantageous to primitive man, who required to subsist to a large extent on roots, berries, grain and fruits, supplemented by what little fish or meat he could secure. It will suffice to note that he required to carry about with him a larger and heavier digestive tract than does civilised man,* and much of the energy which we can now utilise in other ways was utilised by primitive man in extracting nutriment from coarse, fibrous, and more or less nutritious food-stuffs.

With the advent of civilisation there have come the machinery and methods of preparation which strip even the inner husk from the grain, and then grind this already refined food-stuff to an impalpable powder (flour, maize, rice, &c.), to be ready for further preparation by the modern art of cooking. Other means are adopted for extracting merely the juices of roots and plants (sugar). Numberless examples will present themselves to the reader which show how the carbo-hydrates especially are ridded of the fibrous matters with which in the natural state they are mixed. In the case of children's food this process of elimination is carried to a still greater extent, and many children are brought up on softened derivations of food-stuffs administered in the form of paps.

This fact, together with the instinctive dislike of fats and preference for sugar, accounts almost wholly for the relatively greater frequency of caries among children. I need not pursue this subject further. It is tolerably clear that what was at one time performed by the teeth and

* Spencer, "Principles of Sociology," p. 46.

stomach is now too largely done by machinery and cookery. The cause *par excellence* of the prevalence of caries at the present day is the elimination of the fibrous matter which accompanies the carbo-hydrates in their natural state, and their presentation in a form which readily lodges and undergoes acid fermentation in the mouth.

It is important to note, however, that although the food consumed at the present day is conducive to caries, it is not conducive to inherent or developmental deterioration of the structure of the teeth. The enamel is formed below the surface of the mucous membrane, and is complete in form and structure before it cuts the gum, and although the teeth are unused or only partially used, there is no reason to expect a deterioration of structure. Nor do I believe that the temperature of the food given to infants in artificial feeding* has the slightest influence on the developing tooth germs any more than I believe that the hands are imperfectly formed because they are subjected to greater vicissitudes of temperature than the clothed part of the body. This negative belief is supported inductively.

If it could be shown that a deteriorated structure of the teeth had been advantageous to those races in which it might be assumed to have originated, then perhaps by the agencies of natural selection the structural degeneration of the teeth might have been brought about. But this assumption cannot be granted, and truly it would be most

* Cantlie, "Early Decay of Teeth in Great Britain," Sept. 2, 1899, p. 592.

disheartening if we had to believe that the teeth of the present day were so much deteriorated, that the hope of regaining the perfection in structure of the teeth of savages was only to be again arrived at by a process of natural selection. We cannot believe in a degeneration of the teeth themselves unless we wish to believe in the inheritance and augmentation by inheritance of something which is detrimental, an idea which has not even the support of the theory of the preservation and augmentation of useful characteristics through adaptive modifications.

It has been suggested that mixed feeders are more liable to caries than people who subsist almost wholly on meat. No doubt this is true, and it is important to recognise this fact, but it is possible for people to be mixed feeders and even vegetarians, and yet be little prone to caries, *e.g.*, Polynesians, Fiji Islanders, East Indians (Mummery's Tables).* It is impossible to make man a flesh eater except in certain latitudes. As far as my experiments on the lodgeability of food-stuffs in the mouth go, there are certain mixtures which do not tend to lodge in the crevices of the teeth as much as some unmixed food-stuffs. Thus, for example, meat and potatoes, or meat and bread, are much less liable to lodge than are potatoes or bread separately. When fibrous food is chewed together with non-fibrous, the non-fibrous is swallowed first, and the fibrous follows after further chewing. This fact may be easily observed while eating meat and potatoes, the potato being swallowed a considerable time before the meat, which

* Mummery, *Transactions of the Odontological Society*, New Series, vol. ii. p. 7.

requires to be chewed longer. During the process of mastication the bolus is crushed again and again between the molars and bicuspids, and the part which has been partially softened is pressed between the dorsum of the tongue and the rugæ of the palate. The fluid and finely ground part, which is principally carbo-hydrate from the potato mixed with saliva and the other juices, is pressed backward to be swallowed, while the roughened surface of the dorsum of the tongue arrests the passage backwards of the fibrous part of the food by pressing it against the rugæ of the palate. The tongue then returns this fibrous part to the side of the mouth to be further disintegrated. If an unsavoury simile may be used, this process may be likened to the mopping up of the dirt and water from a floor which is being cleaned; the fibrous mop or cloth is rubbed on the floor, and the water and dirt which it gathers up are wrung out into the bucket, and the mop again applied to the floor, the dirt and water soaked up, and the process repeated. This is essentially Nature's method of cleaning the teeth, and is, I believe, more efficacious than a tooth-brush, as it polishes the surface of the teeth and creates a healthy flow of saliva while removing the non-fibrous food-stuffs. This latter function is not performed by the tooth-brush.

The same remarks are applicable to fibrous food-stuffs which contain much starch and require to be chewed. From a physiological point of view also, the fibrous matter, which in the natural state is incorporated with starchy food, ought to be retained, as this necessitates a thorough mastication, and so allows the ptyalin of the saliva to act

upon the starch, and supplies at the same time the requisite inert matter for the proper action of the bowels, as well as supplying the requisite cleansing matter for the teeth. Certain mixed foods, however, do lodge in the teeth when eaten together, *e.g.*, biscuit and cheese, both being non-fibrous.

With regard to food-stuffs in which the coarse and fibrous parts are removed, the beneficial function which these fibrous parts perform in the cleansing of the teeth is lost. In eating a biscuit, for instance, a considerable part of it is crushed into the crevices of, and between, the teeth, and there is no natural method for its removal.

Another effect produced by the elimination of the coarse and fibrous parts of many food-stuffs is to encourage the habit of swallowing the food without much mastication. This is especially the case with children who are brought up on soft foods, and there are, I believe, many people who are so accustomed to eating food that requires little chewing, that they often swallow food unchewed which otherwise would be subjected to a certain amount of mastication. Of course in such cases the teeth are not thoroughly cleaned, and caries is liable to be more frequent.

Now, although civilisation has brought about the removal of Nature's tooth-brush, it is, as it were, an avoidable accident caused by a "want of elementary knowledge of the first principles of digestion," and if we look into the more or less distant future we can easily perceive that civilisation will bring back, in some form or another, that which it is at present so careful to remove,

and we may look forward to the time when the food of the civilised may be less conducive to caries than the food of the uncivilised is to-day. Moreover, there is good ground for believing that with more exact knowledge of the causes and prevention of caries, it may one day become as infrequent as many diseases at one time so prevalent and now so rare.

CHAPTER IV.

CAUSES OF IRREGULARITY OF TEETH.

In the following chapter I intend to direct attention to the forces which conspire to bring about a regular set of teeth, and to try to arrive at some satisfactory explanation of the causes of irregularity, as irregularity is admittedly a predisposing cause of caries, or, as I should prefer to put it, a condition which facilitates the lodgment of food and micro-organisms.

Firstly, I shall refer to the general law that functional activity is antagonistic to growth. I shall assume that the reader is acquainted with this principle, and need say no more on this subject at present than merely to mention that, during gestation, developmental activity is at its maximum and functional activity at its minimum. Akin to this is the fact that, when from disease or other cause a person is confined to bed during the period of growth, a considerable development in the length of the bones takes place. Thus, increase in length of bone takes place independently of functional activity. Furthermore, although an organ or part of the body may be wholly or partially disused for generations, this fact does not tend to diminish the amount of growth in size or structural perfection, or the functional activity of these organs or parts in future

generations (A. R. Wallace,* Weissmann †). Thus, though the ladies of China have for generations had their feet bound up and their normal growth prevented, and though their feet have been practically functionally useless throughout life, their children are born with perfect feet, which grow and are as useful, perfect and large (if they are not subjected to pressure from bandaging) as their mothers' feet ought to have been. I refer to the above principally to point out that the comparative non-use of the jaws at the present day is a wholly inadequate explanation of their want of development.

Were these the only principles we had to deal with, the jaws would grow to pretty much their normal size and shape independent of their functional activity. But there is another consideration which we must bear in mind, that in certain tissues and organs full development is not, as a rule, attained without a normal amount of functional activity.

This is perhaps best seen in the development of muscle. In this case the development is, to a great extent, dependent on the amount of use to which the muscle is put, as in muscle there exists the potentiality for a certain amount of hypertrophy or atrophy according as it is used or unused. In the case of bone there is no hypertrophy or atrophy in length under similar conditions. There is obviously some utility in this hypertrophy or atrophy according as the muscle is used or unused, and this power must be conceded to have been acquired by the germ

* Wallace, "Darwinism," p. 413 *et seq.*

† Weissmann, "Germ Plasm," p. 392.

plasm and the potentiality transmitted hereditarily. On the other hand, beyond the effect which greater use would necessitate in developing bone of attachment, and thickening it and strengthening it, the utility for the acquiring of the potentiality of hypertrophy or atrophy would be of little or no use in bone, and we find it is, as a matter of fact, non-existent as regards development in length. The reason for referring to the above will be observed after further consideration of other circumstances.

Another consideration to which I would call attention is the fact that in bilaterally symmetrical parts variations are generally bilaterally symmetrical, and normal variations, as well even as abnormal ones, are carried out to the most minute details on both sides of the body. It seems as if the potentiality for developing such parts was originally one and the same process; the two sides remain as it were under essentially one denominator, though they are as absolutely different as the right and left hands. However difficult it is to imagine by what means the germ plasm brings about this remarkable bilateral symmetry, there is apparently something conceivable in it, and, as a matter of fact, we know that bilateral symmetry *is* brought about to a very great degree of nicety, though it is perhaps never quite perfect. It might be conceived that, if the jaws were formed by some such method as might be supposed to follow from metameric homology, a certain very definite amount of concomitant variation might be common to both, and so might bring about the accurate antagonism of the teeth which is so necessary, but as the jaws originate from buds from the first visceral

arch, neither bilaterally symmetrical nor metameric variation can help to bring about the perfect arrangement and antagonism of the teeth.

I think we are left with no alternative but to assume that, as far as direct hereditary influence is concerned in the production of the necessary arrangement and relative sizes of the antagonising teeth, there is nothing but correlation in growth to fall back upon.

When we consider that, in order to get an efficient masticatory organ it is necessary that all the teeth should articulate with the greatest nicety, we are brought face to face with one of two alternatives: either the correlation of growth of the upper and lower jaws and teeth must be extremely exact and definite, which it is not, or there must be some controlling influence common to both, which, as it were, guides the teeth to their exact position and arrangement. Nature seems not to miss any means of arriving at the desired result, and I believe both methods are utilised. From some observations which I have made, the concomitant variation of the upper and lower teeth, except in the case of the wisdom tooth, is fairly accurate. However, the arrangement of the teeth is undoubtedly modified by one common denominator, which is the tongue, together with the cheeks and lips. The provision, which nature has accepted to a certain extent, of taking the tongue as a common denominator for the correlation of the arrangement of the upper and lower teeth, is the chief cause of the crowding and irregularity of the teeth of the present generation; because the tongue does not attain, as a rule, at the present day to its normal

size, on account of its functional activity falling far short of normal. The food of the present day is ridded of its coarse and fibrous material, the amount of mastication to which it is subjected is relatively little, and the amount of use to which the tongue is put during the process is much less than when foods were subjected to the relatively great amount of mastication required before the advent of civilisation.

When we remember what has already been said on muscular hypertrophy and atrophy it will be obvious that the muscular fibres are not so thick and numerous as they would be if the tongue were put to ten times the amount of use which it gets when "civilised" foods are masticated.

I have paid some little attention to the size of the tongue in mouths in which there was a large and well-developed arch of teeth, and also in cases in which the arch was contracted, with the result that to all appearances those people who had large tongues had also well-developed arches of teeth, and in those cases in which the tongue was large, the ordinary diet was one which required a considerable amount of mastication.

I had intended making a series of measurements of the breadth of the arches of teeth of savages, as I conceived that on account of the greater amount of use in mastication to which the tongue was put, and the consequent greater size of that organ, that the size, and especially the breadth, of the arches of teeth of savages would be greater than the size of the arches of teeth of the civilised, and more especially than those of the upper classes, who do not give their tongues a normal amount of use in mastica-

tion. Fortunately, however, I discovered that this had already been done, and as the measurements were made independently of the theory which I am putting before you, they may the more readily be accepted as substantiating it.

Dr. Talbot has collected a great number of measurements of the breadth of the upper jaw, or rather of the breadth between the outer sides of the first molars. In the case of the measurements of skulls of savage races collected in various American and European museums, the average breadth was 2·28 inches, while in the measurement of living persons, who were almost all civilised, the average breadth was 2·14 inches. I have not endeavoured to get results suitable for my argument by taking any special cases recorded by Dr. Talbot; he himself says, "In comparing the measurements of the uncivilised races with those of the civilised, it will be observed that the jaws of the former are much larger than those of the latter."* And again, "There is also a marked difference between the diameters of the jaws of dispensary patients and poorer patients and those observed in private practice among the wealthier classes."† He also points out that "the early Britons possessed [upper] jaws which measured from 2·12 to 2·62 in their lateral diameters, while the jaws of the English people measure from 1·88 to 2·44 inches."† Dr. Talbot also points out that among the Europeans the Cretins of Switzerland have large jaws.† This, according

* Talbot, "Etiology of Osseous Deformities of the Head, Face, Jaws, and Teeth," p. 67.

† *Ibid.* p. 66.

to my argument, is to be accounted for by the fact that the tongue among these people is large. The Cretins are doubly interesting in furthering the theory that the tongue gives rise to enlargement of the arch of the teeth, of the alveolus, and perhaps of the rest of the jawbone, as in other respects they are a small and ill-developed people, and they do not use their jaws much in mastication. The tongue is, however, pathologically large. The Esquimaux too have relatively broad and well-developed jaws, but in this case the size of the tongue, and so of the jaw, is brought about normally by their having to masticate an almost wholly fibrous (meat and fish) diet, which generally requires an excessive amount of chewing, being often eaten raw. The stature of the Esquimaux is otherwise small. Now, although Dr. Talbot arrives at the conclusion that the diminished size of the jaws at the present day is due to the crossing of races, his statistics are much more adequately explained by the fact of the diminished size of the tongue depending on the diminished amount of mastication among the civilised. Moreover, his conclusion is at variance with the law that crossing of races tends to reversion to ancestral type. I may state here that I fully admit hereditary, family, and racial differences in the size of the arches of teeth, though combating the theory that the diminished size of the arches of teeth in civilised races is due to anything but the diminished use, and consequent size, of the tongue. Were I writing specially on the irregularity of teeth as a subject in itself, I should enter into this subject much more fully, as it is specially interesting in showing that this acquired characteristic is *not*

inherited. In the meantime I must content myself with a mere outline of what I believe to be the true theory of the causes of the crowding and irregularity of teeth, as it still further strengthens my argument on the etiology of caries.

I shall now direct your attention to certain forces which play an important part in modifying the position of the teeth, namely, the forces arising from the increasing size of the tongue. It is well known that continuous gentle pressure on a tooth causes it to move away from the point of pressure, and when a tooth is thus moved the alveolus follows. I suppose all dentists will admit this, otherwise the mechanical treatment of irregularity would be sheer waste of time. The plasticity of the alveolar part of the jaws is in fact so pronounced, compared with other bones, that we must admit this to be a special hereditary characteristic. With my way of looking at the subject this is to ensure a regular arrangement of the teeth and an exact antagonism, for, were the arches not to a certain extent controlled by the tongue, the slightest variation in shape of the upper and lower arches of teeth would make the dental armature useless for its normal functions.

The modelling of the dental arches round the tongue may now be traced. During the period of suckling the tongue is much used in the process, and grows, and the jaws, which at this time are almost all alveolus, grow rapidly under this stimulus. Owen's remark is suggestive; he says, speaking of the more intellectual as compared with the lower races: "The fore-parts of the upper and lower jaws, concomitantly with earlier weaning, are less produced, and the contour descends more vertically from

the longer and more prominent nasal bones."* During the first six months, while the infant is suckling, the two halves of the lower jaw are separate, and the growth of the bone takes place in the fibro-cellular tissue connecting them. If the tongue is well developed by its activity in suckling, a stimulus is given to the development of bone in the fibro-cellular tissue. The consequence of this is a broadening of the jaw at its anterior part. As regards the lower jaw, the effect of this is to give rise to greater breadth in the neighbourhood of the mental prominence. I have, as yet, not been able sufficiently to verify this inductively, although the few cases I have investigated go to show that the jaw in the region of the mental prominence, that is, the part which is more especially influenced during the suckling period, is better developed in those who have been naturally suckled during infancy. Now, if the sucking process is made too easy, and the tongue does not get a normal amount of exercise, I think we are justified in the assumption that it will not grow so fully as if it were put to a normal amount of activity. At the present day ease in alimentation is fostered nearly from birth. When, in place of the mother's breast, a bottle and india-rubber teat are substituted, the hole through which the milk is to be sucked is made too large, so that the child may suck the milk quickly and easily. If the hole in the rubber teat is made small the child takes too long, and makes too much noise for the patience of the mother or nurse.

* Owen, "Comparative Anatomy and Physiology of the Vertebrates," vol. ii. p. 569.

Now let us direct attention to the stage when the temporary teeth are all in position and completed as far as the crowns are concerned, that is, about the age of three and a half years. At this period the arch of the teeth is regular, and has been brought about in the following manner :—The vital forces bring about the general arrangement of the teeth, and as the teeth and jaws are correlated in their growth, the positions which the teeth come to occupy are to a great extent determined by vital forces. Nevertheless, if we examine carefully the individual teeth as they make their appearance through the gum, we note that they are not so perfectly arranged as after they are fully in position. That is to say, that without the aid of a mechanical force (that is, the tongue, especially) the arrangement of the teeth is imperfect. On coming through the gum the incisors may be found slightly rotated on their axes, or they may appear through the gum in a rather more anterior or posterior position than may be considered normal, and within a certain latitude they vary as regards time of eruption. Although the correlation in growth is sufficiently accurate for the lower teeth to appear at intervals more or less constant from the appearance of the corresponding upper teeth, yet this is not always quite constant, and the lower may not precede or follow the corresponding teeth of the upper jaw in the normal time of succession ; that is to say, the correlation in the eruption and arrangement of the teeth of the upper and lower jaws is not perfect. Now let us consider what happens when, for example, some one or more of the incisors do not grow up to meet the corresponding tooth of the upper

jaw in that most excellently regular arrangement which they as a rule arrive at when the first dentition is complete. Let us assume that one lower incisor is a trifle too anterior, and the other a trifle too posterior. The action of the corresponding upper tooth in biting soon presses more strongly upon the more anterior lower incisor, and this pressure is supplemented by the slight pressure brought upon the upper tooth by the lip. Should the pressure from the under tooth be so great as to slightly displace the upper incisor forward, then the greater part of the pressure of the lip is thrown upon this upper incisor, and presses it backwards. Then the other lower incisor which we have assumed to have erupted a trifle more posterior to its fellow gets greater pressure from the tongue behind it, and is not pressed upon by the corresponding incisor of the upper jaw until it has been moved forward by the pressure of the tip of the tongue. If there is any slight lateral rotation this is rectified in a similar manner. If, from muscular inactivity or other cause, the tongue falls short of its normal size, it is obvious that the teeth will not be forced out so much as they otherwise would have been. Up to this stage, however, the variation in the normal size of the tongue is slight, and so, notwithstanding what has been said about the development of the tongue during the suckling stage, only a trifling want of development of the jaw can be assumed to have been brought about by this cause. Now let us pass to the next stage.

Let us consider the stage when the deciduous teeth have performed their function and are about to begin to be shed. At this period it will be observed that there

generally are slight spaces between the teeth. It is obvious that now the teeth occupy an arc of a larger circle than they did when they first came into position and were in contact. They consequently must have been translated outwards, and the alveolar part of the jaw must have grown outwards also. I do not say that this has been a purely mechanical process, due solely to the increasing size of the tongue, nevertheless the increasing size of the tongue is certainly a factor, if not the chief one. It is well known that the teeth yield in position to a constantly acting force, and if the tongue did not grow normally, the crowns of the teeth would not be forced into this larger arc. Not only do the crowns of the teeth come to occupy a more forward position, or rather, a position in the arc of a larger circle, than they did when first they came into their fully erupted position, but the roots likewise occupy the arc of a larger circle. How this force affects the latter change may be elucidated by the following explanation: the tongue presses upon the backs of, for example, the lower incisors, and so tends to force the crown outwards; this force acts upon the tooth at a certain distance from its apex; the apex of the tooth is, as it were, fixed by the opposing upper tooth, and so the pressure tends to push the tooth bodily forward. To put it in mechanical language, the lower tooth is a lever, the fulcrum is at the apex, where it impinges on the upper tooth, and the power which acts outwards is the tongue, the resistance is the alveolus covering the anterior part of the root. In the upper jaw, the top of the crown of the lower tooth which is forced forward by the enlarging tongue is the power, the

lip pressing against the anterior surface of the lower part of the upper incisor is the fulcrum, and the resistance is the alveolus covering the anterior surface of the root. I do not intend to indicate that this is the sole means of bringing about the outward translation of the tooth, but it acts as a guide to the vital forces in giving rise to the necessary amount of absorption of the posterior surface of the alveolus covering the anterior surfaces of the roots of the incisor teeth, which in its turn stimulates a deposition of bone on the anterior surface of the alveolus. What part the developing crowns of the permanent teeth take in stimulating an outward translation of the roots of these temporary teeth it is difficult to say, but in any case the pressure of the tongue on the teeth is the controlling force, and though the vital forces might be supposed to produce a bodily translation of the tooth, it is ultimately dominated by the pressure of the tongue. I trust I have made it clear that the teeth must have been translated bodily outwards, and that, were it not for the growth of the tongue, the teeth could not possibly have undergone the change in position which is brought about.

During the few years that the deciduous teeth are capable of full functional activity, what must be the effect on the tongue of eating the soft pap, liquid extracts and refined foods of the present day, which require little or no chewing? I think it will be evident, from what has been said on the influence of functional activity on the growth of muscle, that the development of the muscular fibres of the tongue is not as great as if it had been used while chewing fibrous food-stuffs, which require at least ten times

the amount of mastication. The consequence of this is seen in the fact that the deciduous teeth are sometimes not translated outwards, and the spaces which should develop between them do not form, and the alveolar arch is not as broad as it ought to be.

In the next stage the temporary teeth are shed and the permanent ones takes their place, and if the tongue has developed normally, and the deciduous teeth have been translated outwards, with the result that the alveolus has also grown outwards, then there is every probability of the permanent teeth taking up a regular position, even though there has been an irregularity in their eruption, as there frequently is. This is brought about by the same forces as those which have been described as bringing about the regular arrangement of the deciduous teeth. If, however, the tongue has not developed sufficiently, and the temporary teeth have not been translated outwards together with the alveolus, the permanent teeth cannot occupy this contracted arch without irregularity, as the sizes of the crowns of the permanent teeth are considerably greater than the crowns of the temporary set (excepting the temporary molars). If the tongue has not developed by a normal amount of activity, the teeth at the side of the mouth are not forced outwards, but fall inwards. Then the posterior permanent molars begin to take up their position in an arch which is not quite large enough to contain them, and the teeth which have fallen inwards have this available space still further encroached upon by the tendency to forward translation which these molar teeth have. The result is inevitable, and is seen in

V-shaped and saddle-shaped arches, &c. Such a condition often appears to be inherited, as parents, as a rule, bring up their children in much the same style as they were brought up themselves.

In further support of this theory of the causes of irregularity, I would point out that irregularities are most marked in the upper jaw, *i.e.*, the normal expansion of the upper jaw is not so great as that of the lower, and this notwithstanding the fact that the amount of available space for the teeth in the lower jaw is very markedly limited by the ascending ramus. This is caused by the tongue lying in the floor of the mouth, and although its normal size is diminished, yet it keeps up a certain amount of lateral pressure on the lower teeth and alveolus. I think this fact suggests the explanation of the external cusps of the lower teeth frequently falling outside the corresponding cusps of the upper jaw, and also the occurrence of underhung jaws.

There is a current assumption that the early extraction of the temporary teeth gives rise to contraction of the jaw, and although this belief is not shared by all authors, there is certainly much clinical evidence which appears to support it. It is a fact that in mouths where the temporary teeth have been removed early there is, as a rule, in later life a crowding of the permanent teeth which take their place, but the removal of the teeth is not the cause of the irregularity. The temporary teeth are generally extracted early because of their being carious, and caries is brought about by causes similar to those which bring about insufficient development of the tongue

and the contraction of the jaws, viz., principally the elimination of the coarse and fibrous matter from the food-stuffs. Further, when the temporary teeth are prematurely extracted, the outward pressure of the tongue is diminished by the expansion of that organ where the gaps exist, and consequently the remaining teeth are allowed to occupy a slightly smaller arch than they otherwise would have done.

Another fact of importance, when the teeth are not used to masticate more or less fibrous food, is that their upward growth from the alveolus is not completely checked by the opposing teeth; that is, they are not arrested by full functional activity. In childhood, if the food consist of broths, milk puddings, and paps, there is very little functional activity. The consequence of this is that the teeth rise, as it were, in their sockets, and the alveolus accompanies them. This is well seen in cases in which the molars only occlude, and there is an open bite. In this case the development of the alveolus at the front of the mouth is very great, and I have no doubt that the reader has seen an illustration of this condition in the text-books on dental surgery.

My own observations show that a want of full use of the teeth gives rise to high palate, and this is supported by the fact that among patients of the upper classes—who are brought up on soft, refined foods—a high palate is much more frequent than among the working classes. This tends to augment irregularity, as the space for the tongue is vertically larger and the soft parts of the cheek press rather more on the buccal surfaces of the teeth

than does the tongue on the lingual surfaces under normal conditions. More marked cases of high palate are presumably brought about for the following reason. Not only are the food-stuffs so soft that the downward growth of the teeth and alveolus is not quite checked, but also nasal breathing is not fully performed. The mouth is kept almost constantly open, and so further tends to allow of the downward growth of the upper teeth. In these cases, too, the arch is always contracted, as the force of the tongue acts principally only when the mouth is closed, and this force, which normally holds the teeth outwards, is to a great extent diminished, and almost wholly lost as regards the upper jaw. Whether only disease, such as enlarged tonsil, is the cause of this mouth breathing, or whether the habit of nasal breathing is not sufficiently enforced through a normal period of normal suckling, I have so far been unable to find out.

Another point to which I wish to refer. When the teeth are put honestly to perform their natural function, and by the forces which have been referred to a fine broad arch of teeth has been brought about, there is a liability for slight spaces to exist, as in normally developed mouths ample, though not lavish, space is provided for the teeth. When there are slight spaces between the molar or bicuspid teeth, food is apt to lodge, and the teeth on the approximal surfaces are liable to become carious. There is a provision for obviating this, and through this provision the exquisite arrangement of the teeth which we so rarely see in civilised countries is made almost perfect. The molar teeth, after cutting the gum,

grow upward, and, if spaces exist in front of them, are bodily translated forwards. I suppose all dentists have seen numerous cases in which, for example, the second bicuspids above and below have been extracted in youth, the molar teeth have been translated forwards, and the space completely filled up. This change of position, when it occurs under normal circumstances, is not a tilting forward of the crown while the apex of the root remains stationary. The translation comes about, I believe, in the following manner. There is a forward force which is the resultant of the outward and slightly forward pressure of the tongue, and the inward and forward pressure of the buccinator muscle. (These are not imaginary forces, as the mucous membrane of the cheek at the side of and behind the hindmost molars is frequently marked and indented by its pressure on these teeth, and the marks caused by the pressure of the lower teeth on the tongue may also frequently be seen.) The resultant of these forces tilts the crown forward as we occasionally see it in an exaggerated form, and then, if the opposing teeth are not wanting, the posterior cusps occlude with the antagonising tooth. Then there is also the vital force which makes the tooth grow upwards to meet its fellow, but as the posterior part of the tooth is arrested by occlusion with the opposing cusps, the only result of this is the rising of the anterior part of the crowns, and by this motion the roots also are carried forward. However beneficent this force ought under normal conditions to be, under the very abnormal conditions which exist among civilised peoples it becomes a

cause of irregularity, for if the normal arch has fallen in, and is already too small, this force only tends to increase the mischief; so much so is this the case that we frequently see a tooth, for example a second bicuspid, which has been forced inwards out of the arch altogether, while the remaining teeth occupy a more or less regular position.

I have not deemed it advisable to introduce special cases to confirm much of what I have said; it might easily be done, but it would be open to the objection that the cases were selected to confirm my views. I shall therefore content myself with referring to a case the models of which were taken by Mr. Merryweather and are now in the Museum of the Royal College of Surgeons. It is described by Mr. Tomes in the *Transactions of the Odontological Society* for April 1892.* The following extract from Mr. Tomes' "Dental Surgery" will recall the case: ". . . a bilateral asymmetry (which was ultimately met by the extraction of a tooth on one side) had asserted itself at a time when precisely the same teeth had been shed and replaced upon the two sides. Another respect in which the mouth was irregular lay in the height of the lower incisors. These had grown up too high, in spite of the fact that the upper incisors were vertical instead of being inclined outwards; and so the lower incisors, so far from having no opposing teeth, were driven to take a position sloping inwards."† He further says, "Thus two forms

* Tomes, "Studies in the Growth of the Jaws," *Transactions of the Odontological Society*, New Series, 1892, p. 143 *et seq.*

† Tomes, "Dental Surgery," p. 60.

of slight irregularity occurred which could by no possibility be referred to merely mechanical causes." *

Nothing is recorded about the amount of development of the tongue, and as the models were taken recently, one may be justified in assuming that the individual from whom the models were taken had indulged in a "civilised" diet, which means that mastication is reduced to a minimum, and the tongue does not quite develop to what might be considered its normal extent. We are justified in assuming that the tongue *was* rather smaller than what might be considered normal, as the arch of the teeth gives a fairly accurate measurement of it, as it occupies the space within the arch. Now what must be the effect of a small tongue on the incisors? The crowns are not forced or kept forwards, and the lower teeth, instead of meeting the upper lying at an angle which would bring the lower incisors into almost direct contact with the posterior bulge of the upper incisors, fall backwards and meet with no resistance till they grow upwards and are arrested by the pressure of the gum. (Normally the upper incisors are kept from being pushed forward by having the lower ends of their crowns held inwards by the lower lip, and the lower teeth from being forced inwards by the pressure of the tip of the tongue.) With regard to the bilateral asymmetry, this, too, *is* susceptible of a mechanical explanation, though not being sufficiently acquainted with the case I will only hint that the amount of mastication on either side was probably unequal, as it usually is.

From what I have said, it might be assumed that I

* Tomes, "Dental Surgery," p. 61.

believed the vital forces played a small part in the arrangement of the teeth, but this would be a great mistake. I only maintain that Nature does not scorn mechanical forces when it suits her purpose to make use of them. It is difficult to conceive what Nature could be supposed to have been doing if it were assumed that irregularity of the teeth had become an inherited characteristic. Surely irregularity in the arrangement of the teeth cannot be considered beneficial, and that being so, why should natural selection be supposed to have chosen such a disadvantageous peculiarity as a thing worthy of hereditary transmission? If it be said that irregularity of the teeth had come about by spontaneous variation, and the point being of little importance it was allowed to be continued, my reply is that variations from the ancestral type, when they are neither good nor bad, do not get stereotyped, but sink out of existence by continued amphimixis (*e.g.*, polydactylism); that is, in simple language, through dilution, as it were, of the characteristic by intermarriage.* The foregoing explanation of the common forms of crowding of the teeth is not meant to be an exhaustive explanation of all forms of irregularity, nor of the already well-investigated method of the development of the jaw, but merely to supplement the ordinary description with which it is assumed the reader is acquainted, and to direct his attention to the causes of the diminished size of the arch of the teeth, and of the alveolus, among the civilised races at the present day. Where my explanation is contradictory to current theories I mean it to be so, and

* Weissmann, "Germ Plasm," Section "Amphimixis."

however heterodox the explanation may appear to be, I certainly maintain that it is in accord with biological principles, and that therefore it is the current theories on the causes of irregularity which really are behind the times, if they are not heterodox. I further hope that I have shown that there is some tangible cause of irregularity which might be combated, and that the subject may some day be extricated from the hopeless confusion that has hitherto surrounded it.

In conclusion, I would point out that this lengthy digression on the crowding of the teeth has been necessitated by the absence of a rational explanation of its causation, and to enforce still further the fact that the elimination of the coarse and fibrous part of the food is the principal cause of irregularity, and the consequent lodging of food and micro-organisms, and therefore a predisposing cause of caries.

CHAPTER V.

EFFECTS OF IRREGULARITY.

Hitherto I have taken it for granted that irregularity of the teeth predisposes to caries ; I wish now to show *why* it is a predisposing condition. In order to elucidate this point I shall recall to the reader a condition which he may have observed, or if not, which he may easily observe on directing his attention to the subject. When caries starts at the neck of a tooth it will be noticed that it commences at a slight distance from the edge of the gum. The part which exhibits, in the early stages, the maximum amount of decalcification is removed from the edge of the gum about a millimetre. Now, if the crevice formed by the edge of the gum and the neighbouring part of the tooth be filled with food, as it frequently is, it will be observed that the greatest depth of food is immediately under the gum, and not a millimetre from it. From this it is presumable that the gum exercises an influence antagonistic to the formation of acid. This is further supported by the fact that at almost the same place in certain mouths there is a deposit of tartar. However, the tartar is deposited close to the gum, and in fact, if the formation is not great, at the distance of a millimetre from the gum there is no deposit of tartar at all. This

may be easily seen at the neck of the canine, where either of these conditions may be found with almost equal frequency.

The observation of these facts led me to doubt the truth of the current statement that the secretion of the gum was slightly acid. I therefore tested the reaction of the secretion, and at first it appeared correct, but on further testing I found that the reaction varied at different parts—that, in fact, round the necks of the teeth the reaction of the secretion after cleansing the mouth was distinctly *alkaline*. This may be verified by moulding a piece of wet litmus paper into the crevices at the gingival margin.

The *rationale*, no doubt, of the slight acidity of the secretion of the gums is to prevent to a certain extent the flourishing of the micro-organisms of the mouth, and although the alkalinity at the gum margin allows of a rapid development of micro-organisms, the amount and strength of the alkaline solution is in fairly clean mouths sufficient to keep the teeth from destruction by acid produced in fermentation. It will be observed, however, that it would only increase the number and activity of the mouth bacteria if the secretion of the mucous membrane at all parts were alkaline, as these micro-organisms grow best in a slightly alkaline medium.* I think it will be noticed that this distribution of acidity and alkalinity is the best possible for the prevention of caries. It suggests caution in using alkaline mouth washes.

* Goadby, "Bacteriology of the Mouth," *Transactions of the Odontological Society*, 1898, p. 179.

In the regular arrangement of the teeth the spaces between them are V-shaped, the apex of the V being directed upwards in the case of the lower teeth. The gum bulges into this wedge-shaped space, and so very little of the approximal surfaces of the teeth is more than a millimetre removed from the gum when it has not receded. Further, it will be observed that the piece of gum filling this space presents a large surface of gum—and so secreting surface—to the approximal surface of the teeth, and we may well be justified in assuming that the antacid or neutralising action of this is two or three times as strong as in the case of the eye-tooth at the spot referred to, especially as the action of the lip is not so near as it is at the buccal side of the neck of the eye-tooth.

If acid-forming food does lodge in these spaces it must be small in amount, and not only is there the influence of the gum to check the amount of acid formed where certain foods lodge, but there is also the neutralising action of the saliva, which, when mastication is thoroughly performed, is constantly rushing through these spaces, and so tending to dislodge any food or acid which may be there. When, however, the arch of teeth is irregular, this V-shaped interspace is nearly obliterated, and the teeth frequently have a relatively long line of contact, or even a surface of contact, extending from the neck of the tooth to near the coronal surface. The beneficial action of the secretions of the gum on the fermenting food, if it lodges in such places, is at a greater distance than in the normal V-shaped spaces, and there is a diminished gum surface to throw out the alkaline secretion. Moreover, irregular teeth often lodge

food-stuffs more readily than regular teeth. Another effect of irregular teeth is to keep off the tongue and cheeks from the less inwardly or outwardly projecting teeth, and to diminish the amount of cleansing by the friction of the tongue and cheeks and of the movements of the saliva over certain protected parts of the irregular teeth.

While speaking of the influence of the gums in thus being a prominent factor in the prevention of caries, I may refer to the fact that some authors appear to blame the secretions of the gums, not only for being slightly acid, but also for being normally viscid and a cause of caries. I can at will produce a viscid coating over my teeth by eating sweets, and after having set others to do likewise have found the same coating on their teeth. I see no reason whatever to blame the gums for this condition, especially as cane sugar stimulates the secretion of mucous and is known to undergo a viscous or mannitic fermentation. Schützenberger gives the following equation, which will explain what theoretically takes place:

$$\underset{\text{Cane sugar}}{25(C_{12}H_{22}O_{11})} + \underset{\text{Water}}{25(H_2O)} =$$

$$\underset{\text{Gum}}{12(C_{12}H_{20}O_{10})} + \underset{\text{Mannite}}{24(C_6H_{14}O_6)} + \underset{\text{Carb. diox.}}{12(CO_2)} + \underset{\text{Water.}}{12(H_2O)}.^{*}$$

No doubt this viscous gum acts as a very effective barrier to the beneficent influence of the saliva, and as this fermentation takes place along with lactic acid and other fermentations, and the deposited gum acts as a food-catcher, retainer, and acid fermentation protector, we need scarcely wonder that there is a popular impression that

* Schützenberger, "Fermentation," p. 292.

sweets are bad for the teeth. It may here be observed that sugar does not *appear* to be one of the lodgeable food-stuffs, and when it is consumed quickly alone, or with fibrous foods, little or no lodging results. But if it be taken in the form of sweets, which gradually melt and are swallowed, and if this be persisted in for some considerable time, there is continuously a little converted into gum by the viscous fermentation. This accumulates as long as the eating of sweets is continued. It is impossible to observe the coating after eating a little sugar when the teeth are originally well cleaned, and in order to get the gummy coating well marked it is necessary to eat sweets more or less continuously for hours. Similarly when grapes are eaten to a great extent, as in the "grape cure," the same results seem to be brought about by the continuous supply of sugar, and on account of the skins not being chewed, and the presence of the pips encouraging merely the bursting of the grape, practically no chewing is performed, and the resulting effect on the teeth is injurious. So, when infants are given a sucking-bag, to soothe them, containing sugar and milk, there is rapid destruction of the teeth.

The gummy deposit of the mannitic fermentation does not become formed when cane sugar is taken even in quantity if the fibrous part of the sugar cane is chewed with the sugar, as the juices are swallowed before the mastication is finished, and the fibrous part of the cane cleanses the teeth more effectually than a tooth-brush in the manner I have already pointed out, and further the salivary and other secretions are sufficiently stimulated to

be able to carry away the sugar before mannitic or other fermentation has had time to take place. On the other hand, the viscidity due to mannitic fermentation is seen in an exaggerated degree when salivary secretions are more or less arrested, as in some fevers.

Having shown in what manner the crowding of the teeth very seriously increases the liability to be attacked by caries, I shall now refer briefly to two theories of the causes of crowding of teeth, which have gained currency in our best text-books on dental surgery. I shall firstly refer to the theory that children may inherit large teeth from one parent while inheriting small jaws from the other.* Were this theory true we might equally expect to find teeth set widely apart through the inheritance of small teeth from one parent and large jaws from the other; but we do not. Mr. Tomes has brought forward evidence which goes a long way to prove that the growth of the body of the jaws is greatly dependent on the developing teeth. On *à priori* grounds we may be justified in going still further by saying that the *size* of the body of the jaw is greatly dependent on the *size* of the crowns of the developing teeth. The growth of the jaws and teeth are intimately associated, and from what has been already said, we may be pretty certain that the teeth and jaws are closely correlated in their growth. I think we are, therefore, compelled to dismiss this piecemeal conception of hereditary transmission, just as we would discard any theory of heredity which would have us believe that we

* Smale and Colyer, "Diseases and Injuries of the Teeth," p. 40.

might inherit the right leg from one parent and the left from the other.

With regard to the second theory of the causation of crowding, namely, the theory that sexual selection has brought about a diminished size of jaw and a consequent inability for it to afford room for ample dental arches, Mr. Tomes, while admitting that much may be said against the theory, argues as follows:—"For if the type of face nowadays considered to be beautiful be investigated, it will be found that the oval, tapering face with a small mouth, &c., does not afford much room for ample dental arches. On the other hand, the type of face which we considered bestial has a powerful jaw development. Perhaps generations after generations seeking refinement in their wives may have unconsciously selected those whose type of face hardly allows the possibility of a regular arrangement of the full number of teeth."*

Now on æsthetic points there is room for considerable divergence of opinion, and I have no doubt there are many artists who consider a well-developed chin and mental prominence to be a characteristic which is certainly more human than bestial, and that the broad dental arches giving fulness to, and preventing the falling in of, the cheeks, and consequent prominence of the cheek bones, may help to beautify a face. So, too, full arches of teeth prevent the inane appearance caused by the falling in of the arch in the canine region. Nor is the oral orifice necessarily large when the oral cavity is large; indeed, the oral orifice *appears* somewhat smaller when the arch of

* Tomes, "Dental Surgery," p. 112.

teeth is of normal breadth. Add to this the fact that crowding of the teeth very frequently gives rise to anterior protrusion of the upper incisors, and then add the effects of the greater frequency of caries, toothache, probable loss of teeth, possibly suppurating roots, anæmia, digestive troubles, ill health, ill temper, &c., following in their wake, and we may be justified in doubting whether man did, generation after generation, select such types. But let us look at the question from another point of view. If there has arisen in man an unconscious preference for small-jawed women, this must have come about in one of two ways; either those possessing this instinctive preference have survived, and the others, who did not possess it, have fallen out of existence, or there must have been a superorganic evolution of an ideal of beauty which was more or less universally recognised. I think the former idea is out of the question, and the latter would have no appreciable effect, compared with the natural, inherent, powerful passion which attracts the sexes. Since Darwin's time, ideas on the subject of sexual selection have been greatly modified, and with regard to mankind, further than the effect which it has in selecting types with qualities arising from full vitality, good health and its concomitants, it has little effect, and it must always be ultimately controlled by natural selection.*

Now let us consider what must have been the effect of natural selection on the teeth since the advent of civilisation, or since many of the food-stuffs were more or less ridded by machinery and injudicious cookery of their

* Wallace, "Darwinism," pp. 265 *et seq.*, and 294.

accompanying fibrous part. I have pointed out that this gives rise to a diminished size of tongue, to a crowded and irregular set of teeth, and to caries. We know that, when an organ breaks down from the effects of disease, the individual is at a disadvantage in the struggle for existence. That this is recognised with regard to the organs of mastication need hardly be more than mentioned, as already many civil, military and public appointments may not be held by those who have bad teeth, and indirectly the influence of diseased teeth on the general health is only too well known. Unfortunately, too, the influence on the general health may extend over the larger and more important part of a lifetime. Now dental caries is said to be the most prevalent disease that afflicts mankind, and irregularity of the teeth is the rule rather than the exception among the civilised. Since this very prevalent condition of irregularity predisposes to caries and its consequences, it will be obvious that those people who have rather small teeth will be more likely to have a regular set of teeth, as such teeth will be able to arrange themselves round the small civilised tongue with regularity. Consequently, since the advent of civilisation, and concomitant refinement of food-stuffs, those people with large teeth were likelier to be at a disadvantage in the struggle for existence through a considerable predisposition to a very prevalent disease, and so, on the whole, left fewer offspring than did those with relatively small teeth. We should also expect from this cause a correlative diminution of the alveolar part of the jaw at least. Now if we compare well-developed teeth among the uncivilised with well-

developed teeth among the civilised, we find that the teeth of the latter have diminished in size. This theory therefore we see is strictly in accordance with facts accumulated inductively. We find, however, that the mental prominence is more developed among the highly civilised, and this suggests the explanation of the reason of the existence of the mental prominence. I think it might be reasonably supposed that it is, as it were, the rudiment of the more anterior prolongation of the body of the mandible in lower animals.

We find, too, that the wisdom tooth, more than any other, has diminished in size. This, according to the theory which I have put forward, is to be accounted for in the following way. As was pointed out in a previous chapter, the position of the teeth is determined to a great extent by the tongue. Now if during the advance of civilisation the tongue, from the causes mentioned, has diminished in size, the prominence of the teeth, and so of the basi-alveolar line, must have diminished anteriorly, and has brought about orthognathism. The whole arch of the teeth must be more posterior, and if the diminished size of the tongue is slight, as we may assume it was in the earlier stages of civilisation, the arch of teeth would tend to be regular until the appearance of the wisdom tooth. When, however, the tooth is taking up its position, the more posterior position of the rest of the teeth makes it press unduly from behind, and either the whole arch of teeth must be thrust forward, and a space be formed in front of the tongue, or some one or more of the teeth must take up an irregular position, and this latter we know does

occur. Now as this would predispose to caries (and we know that even the most savage races are not wholly exempt from this disease) and the sequelæ already referred to, those individuals with relatively small wisdom teeth would have the advantage, and have a greater chance of leaving offspring than would those who had large wisdom teeth, and unlike the more anterior teeth, variability in shape during the diminution in size would be of relatively little consequence. Thus we have a substantial reason for the more rapid diminution in size of the wisdom tooth than of any of the others of the series without assuming the inheritance of acquired characteristics. Hence, too, arises the benefit of retarded eruption of the wisdom teeth.

CHAPTER VI.

RECESSION OF THE GUMS.

I WISH now to refer to a condition predisposing to the occurrence of caries to which I have hitherto not alluded, and though it is not always recognised it is mentioned by Dr. Miller as a predisposing cause. I refer to the recession of the gums. This condition is often accompanied by the formation of a deposit of tartar at the neck of the tooth, and as long as this remains the subjacent tooth is not attacked by caries. Nevertheless as the recession of the gum takes place, whether caused by this tartar or otherwise, it is obvious that the part of the crown of the tooth which is normally near to the edge of the gum gradually becomes more or less distant from it, and so becomes less subject to the beneficent effect of the alkaline secretions at the edge of the gum. Moreover the spaces between the teeth gradually become larger on account of the recession of the gum, and more food is apt to lodge in such situations. Although the irritation of this slowly formed dark tartar may possibly stimulate the secretion in their neighbourhood, still when the gums have receded a certain distance, the amount of food which lodges in the interstitial spaces gives rise to too much acid fermentation for even this to control ; consequently caries takes place. As

we know, this condition generally occurs after early middle life, and is said to be natural to old age. When this disease becomes acute it is spoken of as pyorrhœa alveolaris on account of the slight oozing of pus round the neck of the tooth in many cases. With regard to this disease Mr. Tomes says, "the causes and pathology of the disease are very obscure." This unfortunately is very true. Perhaps the best and most recent investigation of the subject is that of Dr. Miller, who says, "In my opinion three factors are to be taken into consideration in every case of pyorrhœa alveolaris: (1) predisposing circumstances, (2) local irritations, (3) bacteria." As predisposing circumstances he mentions constitutional and local complaints, abnormal composition of the blood, digestive troubles, unfavourable hygienic conditions (poor quarters, bad food, bad air, want of exercise), and then gives a catalogue of diseases mentioned by various authors, chief among which he seems to consider rickets. As local irritants he mentions tartar, food particles, or any other chemical or mechanical agent. With regard to bacteria, he says it is not caused by any *specific bacterium*, but does not claim to be able to form any decision as to whether local irritants be at all requisite to the initiation of the disease, although he thinks it unquestionably certain that the symptoms are greatly aggravated by local irritations.*

I do not intend to go into the pathology of this disease, but merely to point out the principal initial causes. Before doing so, however, I must remind the reader of what I pointed out in the last chapter, namely, that the

* Miller, "Micro-organisms of the Human Mouth," p. 330.

secretion of the gum at the neck of the tooth is alkaline. This appears to me to point to the rational explanation of the cause of this disease. There are two more or less distinctly differentiated types of tartar, one light brown in colour, generally deposited on the outer surface of the upper molar teeth, opposite the opening of Steno's duct, and on the back of the lower incisor teeth. This tartar is obviously, and is known to be, a deposit from the saliva. The other form of tartar is dark in colour, harder and relatively small in amount, and is formed at the necks of the teeth close to and even under cover of the margin of the gum. Before it was recognised that the secretion in this situation was alkaline, it was naturally practically impossible to account for the presence of the tartar, and hence the peculiar conjectures as to its cause; but on recognising this fact it becomes obvious that this hard dark tartar is a deposit from this alkaline secretion. Under natural conditions and normal stimulation this secretion does not give rise to any deposit at the neck of the teeth, as in savages, and in wild animals in their natural state. It may here be asked, what is this natural and normal stimulation? and the answer is the mastication of coarse and fibrous food-stuffs, for when such foods are masticated, the slight amount of motion allowed the tooth by its means of fixture by the periodontal membrane creates a normal flow of this slightly alkaline secretion; but if the food is ridded of its coarse and fibrous part the secretion is allowed to stagnate more or less and the deposit is very apt to occur. Furthermore, as I have so often pointed out, the food when ridded of its fibrous part

is liable to lodge, the food and micro-organisms are not brushed away, and the micro-organisms which are usually found in such quantities in these situations give rise to their various pathogenic products. These act upon the gum and give rise to inflammation, chronic or acute, and going deeper disorganise the periodontal membrane and surrounding alveolus independently at times of the hard tartar, which, when it forms, augments the irritation and the disease. I think, to those acquainted with the morbid anatomy in the several stages of this disease, the above explanation of its causation may appear at least a plausible hypothesis.

Dr. Miller, in his investigation on this subject, says, "Wild animals kept in captivity, lap-dogs, especially pugs and other ladies' dogs, which have little exercise and eat all kinds of unhealthy stuff, very often lose their teeth, exhibiting symptoms characteristic of pyorrhœa alveolaris, while, as far as I could find out, hunting dogs and such as live under natural conditions are never, or but rarely, afflicted with it. Dr. Fröhner, professor at the Veterinary High School of Berlin, informed me that particularly dogs that are fed on potatoes, farinaceous foods, and sugar are often afflicted with this disease." *

It may be asked what is meant by "all kinds of unhealthy stuff," and though no food is specified by Dr. Miller, my answer would be, food that is refined, similar to the food which the ladies themselves are accustomed to eat, these lap-dogs sharing as a rule the food which is prepared for the table. With regard to the foods men-

* Miller, "Micro-organisms of the Human Mouth," p. 332.

tioned by Dr. Fröhner, they will be observed to be foods which have been ridded of the fibrous part and prepared, as in the case of potatoes, in a manner which disintegrates the little fibre which they possess.

A case is recorded by Mr. Bland Sutton, of a monkey in which on one side the teeth were almost exposed to the ends of the roots, and were covered with tartar, while on the other side the teeth showed only incipient signs of the progress of the disease. Of this case Mr. Tomes says: "The tartar is mainly of the soft, light-coloured kind, and it extends up upon the working surfaces of the teeth, so that it proves conclusively that this side of the mouth was out of work in the way of mastication for a considerable time prior to the animal's death." This case indicates clearly that the side with the advanced disease had not been functionally active for some considerable time, and that the presence of the disease, however initiated, had ultimately rendered the teeth so tender that the other, the relatively healthy side, became, to a certain extent, functionally inactive, and so had commenced to give rise to the disease on this side also. Innumerable examples of similar conditions from similar causes may be observed in the human subject; I refer more particularly to animals to indicate that if men have a constitutional tendency to take this disease, animals are, under similar conditions, predisposed to it also.

In the human subject it will often be observed that teeth which have no antagonists are very liable to be lost by recession of the gum. These teeth are of course functionally inactive, as is the case also with prominent

and outstanding teeth in the front of the mouth. I need not say more to enforce my argument that the elimination of those fibrous food-stuffs which put the teeth to full functional activity is conducive to the recession of the gums, and so to a condition which predisposes to caries.

By the above I do not mean to infer that there are no constitutional causes of the recession of the gums, for indeed if from any cause there is diminished vitality of the gum and inability to resist the irritants which are liable to lodge at the neck of the tooth, it matters little whether it comes from senility or disease, or from lack of the use which is necessary for maintaining the cleanliness and physiological activity of the part.

CHAPTER VII.

FOOD-STUFFS.

I SHALL now direct attention to the food-stuffs which are commonly consumed, and in doing so I shall lightly touch upon the origin and progress of this investigation.

Nearly ten years ago when I started as a student in dentistry I was fresh from the study of biology, and at my brother's instigation became particularly interested in the question of the transmissibility of acquired characteristics by inheritance, and being persuaded that a correct solution of this problem was necessary in order to form true conclusions, not only with regard to biological, but also to psychological, educational, political, and ethical problems, I pursued the subject further. Notwithstanding my great admiration for Mr. Spencer's judgment, I came to the conclusion that those who maintained that acquired characteristics were not transmissible had the best of the argument, and consequently held this view. It occurred to me, however, that if this view were correct then the idea that heredity is an "important factor" in the causation of dental caries must be wholly a mistake. I was, therefore, left to consider whether it might be due to defects in the development of the teeth from defective hygienic conditions or disease, or whether it was due to the condition of

the mouth brought about by the food which was consumed. With regard to the defective development idea I felt that it was inadequate, for except in those few cases of imperfect development such as we see in honeycombed teeth, the teeth in themselves exhibited almost invariably an appearance which to me seemed delightfully perfect, nor did the results of chemical and microscopical investigation, made by others in the meantime, support this hypothesis. For these and other reasons I gave up the developmental idea and devoted my attention to the food. My method of investigation at first was simply to ask patients what food they ate, in order to find which were most harmful. I then constructed hypotheses that such and such foods were bad and asked specially about those. I found that though some of my hypotheses were generally wrong, that some were apparently pretty correct. For years I pursued this method, and in a general way seemed to have a fairly good idea of what foods were or were not harmful. I then made several experiments on the lodgeability of food-stuffs, and found that the food-stuffs which perhaps might have been expected to lodge did not, and *vice versâ*. It was not until about two years ago that I observed that it was not so much any particular food-stuffs which seemed to induce caries as the elimination of the fibrous part and its destruction by most methods of cookery. I had, in fact, been searching for about seven years for something injurious *in* the food, and had not observed that the *absence* of the fibrous part (which cleans the teeth during mastication) was a very considerable factor in the causation of the disease.

I now intend to put before you a table of food-stuffs, knowledge of which has been gained from these clinical investigations and experiments, and from acquaintance with the food-stuffs of savages with little dental caries, and classified according to the theory which I have been advancing.

(1) Foods from which the fibrous part has been removed by machinery and often reduced to powder—*e.g.*, wheat flour, Indian corn flour, rice and farinaceous food generally. Derivatives of above—*e.g.*, biscuits, white bread.

(2) Food from which the fibrous part is totally excluded, the food being derived from a liquid extract—*e.g.*, sugar, sweets, malt extract, extract of meat, and generally the chemical foods and perfect (?) foods advertised for children.

(3) Foods which have the fibrous part almost wholly destroyed by cookery, and frequently have it further eliminated by the process of "putting through a sieve"—*e.g.*, soups, broths, stewed fruits, potatoes.

(4) Foods which are subjected to more than one of the above processes — *e.g.*, milk puddings, jams and fruit-jelly, preserves, sauces, and toast.

(5) Foods in which the fibrous part is retained (sometimes partly destroyed by cookery)—*e.g.*, coarsely ground wholemeal bread, sugar-cane, fresh fruits, raw vegetables, some cooked vegetables, fish, poultry, pork, beef, mutton, tripe.

Some foods which do lodge may not directly undergo acid fermentation, and only do harm by augmenting the number of micro-organisms, and helping to retain some of

the carbo-hydrates with which they are generally consumed. These are more conducive to irritating the gums and inducing recession. It will be observed that the principal difference between the food of savages and that of the civilised is physical, though it must be remembered that boiled starch is more rapidly decomposed in the mouth than is unboiled starch.

In estimating the share that these food-stuffs take in the causation of caries, it is of course necessary to take into consideration the various conditions which have been spoken of in previous chapters, and it is especially necessary to bear in mind that in certain combinations the fibrous food annuls to a great extent the harmfulness of the non-fibrous—*e.g.*, meat and potatoes, mutton and jelly, pork and apple sauce, game and bread sauce, fish and white sauce, bacon and toasted bread.

Whether the fact of foods being cooked in fat diminishes their lodgeability as it diminishes the convertibility of starch into sugar and acid, and whether the acids in some fresh fruits and vegetables tend to dissolve the gummy coating which often covers parts of the teeth, I can as yet hardly say. In any case, the amount of benefit got in these ways appears to be very little, if any.

The following generalisation will be found to put in a few words the conclusion at which I have arrived. It will moreover be found, I think, to be a satisfactory answer to the common question, why the teeth of the present generation are so liable to become decayed.

The cause of the prevalence of dental caries is that the natural food-stuffs are to a large extent ridded of their

accompanying fibrous parts, and prepared and consumed in a manner which renders them liable to lodge and undergo acid fermentation in the mouth; while from this same cause and the induced conditions the micro organisms of the mouth lodge and multiply, and augment the rapidity and intensity of the acid fermentation.

CHAPTER VIII.

PREVENTION OF DECAY IN TEETH.

In writing upon the causes of a disease such as dental caries, one is continually conscious that the ultimate object is the prevention of the disease. In this chapter, however, I intend treating of the prevention of dental caries in order to direct attention to the causes from a different point of view, and to advance further arguments in support of the conclusions as to the cause of its prevalence, for "only by varied iteration can alien conclusions be forced upon reluctant minds." The reader may almost surmise the method of prevention which is about to be advocated. It is that the diet of the civilised must be altered in order to suit the physiological requirements of the teeth, but before entering upon this subject it will be necessary to discuss some psychological considerations. It is quite useless to advocate something which is antagonistic to the instincts and desires of the great majority; we know that although men are perfectly alive to the fact that certain conduct, *e.g.*, intemperance, will bring about certain results, and though those results may be more harmful and painful than those brought about by caries, if the desire for the alcoholic stimulant be considerable it is folly to advocate a method of treatment

which does not take into account a consideration of this desire and its probable results.

It has for some time past been recognised and insisted upon that beneficial results to the teeth are certain to accrue from the constant use of the tooth-brush, but we know that this method of keeping the teeth in good order is *not* resorted to by the great majority of those who will readily admit that its use night and morning would save them a considerable amount of pain and anxiety on coming to the dentist. Even dentists themselves who are daily insisting on their patients brushing their teeth are frequently delinquents in this matter, and since this is so, we need hardly wonder that children sometimes forget the use of the tooth-brush. This method of preserving the teeth has been insisted on for some considerable time, and yet caries is on the increase, and that too among the very class in which the benefit from such a procedure is most thoroughly recognised. I think that this method has had a fair trial, and that, partly perhaps from the impossibility of getting people to do it, and partly from other reasons, it is futile to expect from this means *alone* any substantial change for the better in the condition of the teeth.

If I advocate that the fibrous matter which accompanies the carbohydrates in their natural state should not be eliminated, or if eliminated that it should be consumed together with or followed by some food-stuff which is fibrous, *e.g.*, meat, the question arises, Would people do this, even though they were thoroughly persuaded that this would prevent the decay in their teeth? Even the most sanguine who have had, for example, to advocate

dieting patients for dyspepsia, might despair of this method. Nor can we be altogether hopeful that mothers would change the food of their children, and bring it into accord with the physiological requirements of the teeth. Still, there is a numerous and increasing class of women who do make some attempt to acquaint themselves with the principles of physiology, and more especially of hygiene and dietetics, and bring up their families accordingly. Among this class we may be hopeful of success to some slight extent. Then there are many people who are not very particular what they eat, and by whom little selection in the matter of food is made. These people are in the habit of eating whatever is put before them, and as they pay little attention to dietetics, they simply eat whatever is considered good, wholesome, food, so that this class is particularly amenable to the treatment about to be advocated. In fact, as it is, those men who are not too dainty in their tastes, and who will not discard a piece of meat or other food-stuff because it is a trifle tough, generally have a fairly good set of teeth. Some men indeed, have a decided preference for eating things which they can feel between their teeth and which require to be chewed. Possibly it is to a certain extent due to their being deprived of a reasonable amount of fibrous food requiring chewing that some men satisfy their instinctive desire to masticate by chewing tobacco. Perhaps also it is this same instinct which makes many children relish so highly such a food-stuff (if it may be so termed) as liquorice-root. Certainly in countries where it grows, children greatly relish eating sugar-cane. In this latter

case there is in addition the satisfaction of gratifying the physiological requirement which the child has for sugar. In civilised countries, however, the craze for the elimination of the innutritious fibre, and the taking of the sugar in a form which can be wholly assimilated, prevents the importation of the fibre into the country, and the physiological necessity of the alimentary canal for non-assimilable matter is met by the sweeping down of some assimilable matter with a liquid extract or powder of liquorice.

But let us consider the subject from the beginning. It is, of course, necessary that an infant or child should be brought up under hygienic conditions in general, in order that the normal growth may take place. The natural food, of course, ought if possible, to be given, *i.e.*, mother's milk, and when the teeth are about to come through the gum, teething powders containing mercury should *not* be given, as it appears that mercury has a specific action on the developing enamel and gives rise to a very ugly mark, caused by arrested or mal-development of the enamel which in later life is liable to lodge micro-organisms and food-stuffs. A similar condition sometimes apparently brought about by the exanthemata may be avoided by hygienic means. So, too, syphilitic teeth may be avoided by proper precautions.

As regards the diet of children after the teeth have come into position their natural instinctive preferences are on the whole a very good guide, but these are very different from the guides which are followed. Perhaps the great majority of children after they have got their complete set of temporary teeth have a dietary such as the following:

Breakfast.—Bread and milk or porridge. Milk, tea, coffee, or cocoa. Bread and butter, perhaps an egg.

Dinner.—Potatoes and gravy or meat. Milk pudding.

Tea.—Milk or tea with bread and butter. Jam. Cakes.

Supper.—Bread or biscuit and milk.

Such a diet as the above is not sufficiently varied, and as will be observed from what has been said, it is on the whole a very bad one for the teeth, and it would indeed be difficult to choose a diet so well calculated to bring on caries. With the exception of the meat at the mid-day meal almost everything is apparently calculated to lodge and undergo rapid acid fermentation. The milk which is often a prominent part of young people's diet may, indeed, be harmless when consumed alone, as under such conditions it does not lodge to any appreciable extent, but when it is taken with toast, biscuits, milk puddings, &c., it is apt to a certain extent to lodge with such lodgeable food-stuffs and promote the rapidity of the acid fermentation.

Now let us consider what might be an improvement from the point of view of the preservation of the teeth, while at the same time keeping the diet as good, if not better, from the point of view of the physiological requirements of the body. I think it would be found advantageous for children who are undergoing rapid development to have more albuminous matter, and inasmuch as eggs are not fibrous and do not clean the teeth to any extent

during mastication, nor are they particularly easily digested, this concentrated form of albumen might be limited in amount, and a considerable amount of fibrous albuminous matter could be taken instead. Thus, at breakfast, fish or bacon might always be taken in sufficient quantity to ensure mastication and the cleaning of the teeth. The toast or bread had better, too, be changed for coarsely ground whole-meal bread.

With regard to the children's midday meal, the potatoes might be supplemented by vegetables, preferably in the raw form, such as salad, and along with the meat also, if more carbohydrates be deemed necessary, boiled rice, Yorkshire pudding, jelly, or other suitable adjunct to the particular kind of meat or fish might be taken without harm resulting. Then fruit might be given to finish the meal. I think if fresh vegetables and fruit were more in the routine of children's food, it would prevent the violent excesses sometimes indulged in when children get into an orchard, or even a turnip-field, on some special occasion. There is no doubt that the continual non-satisfaction of the physiological want of vegetable acids and possibly uncooked fibre, is the chief reason for the excess sometimes indulged in, and at least it is improbable that if children had a proper amount of wholesome, ripe fruit and fresh vegetables, they would be likely to take an excessive quantity of unripe fruit when occasion offered.

Then with regard to the tea, bread, jam, and cake. This again is a particularly harmful meal. The bread should be of the whole-meal variety, stale, and it might

be eaten in the form of cress or tomato sandwiches. If jam or jelly is taken, it ought to be supped alone, or with cream or milk, and swallowed without mastication, and followed by something fibrous. A little fruit might preferably be substituted for jam at this meal too, or better still, some sugar-cane might be chewed. The liquid, *i.e.*, the tea, should be taken *after* all that is to be eaten has been eaten.

With regard to supper, if milk alone is not sufficient and it be deemed necessary to have something more substantial, then fish or some light meat should be eaten with the bread.

What I have just said is in no way meant to indicate the dietary necessary for children, but to show the practical application of my theory to the prevention of caries, and to point out that it is possible, even under existing circumstances, to give a child sufficient albuminous, amylaceous, fatty, saccharine, mineral, and innutritious matter, without everlasting milk puddings and bread and milk. That is to say, the physiological requirements o the body may be satisfied while giving the child a diet *necessitating* the learning of the habit of mastication, which is very important from a stomachic point of view, as well as from the point of view of the preservation of the temporary teeth till the permanent ones are ready to take their place in a regular and natural manner. When we consider the ugliness and the remote consequences of an irregular set of teeth, I think it will be admitted that the extra amount of chewing which would be necessitated by the diet advocated would be well compensated for

even though it only partially diminished the amount of caries and the irregularity of the teeth.

With regard to the diet of adults further suggestions here are hardly necessary. These may be found in previous chapters. Fortunately there is among adults a greater freedom to eat what is gratifying, and to eschew what is not, and notwithstanding the temptation of refined foods, undoubtedly there exists in some people, especially men, a gratification in eating what requires a decided amount of chewing.

In considering the prevention of dental caries it will be well to refer to the filling of teeth, for, as a rule, fillings are inserted with a view, not only to arresting the progress of caries, but also to prevent its recurrence in the neighbourhood of the filling. So long as we dentists are ignorant of the cause of caries, and the conditions which give rise to it, so long as we are content to assume, erroneously, that heredity, civilisation, deterioration in structure of the teeth, constitutional causes, abnormalities of the buccal secretions, &c., are in part or wholly, the causes of the disease, then so long must the operation of filling be an empirical operation. When, however, we distinctly recognise the cause of caries, and the conditions which are necessary antecedents, positive and negative, then it emerges from empiricism, and becomes a scientific operation. Recognising that food lodges in crevices, &c., and that this food forms a suitable nidus for acid fermentation, then all fillings must be so shaped that no food may lodge at the edges of the filling.

When, for example, a filling is inserted in a crown cavity, say of a molar tooth, it is necessary that the decay should be removed, but further than this, the junction of the filling, and the tooth must not be made in any hollow which would presumably lodge food, nor must the surface of the filling form an angle with the neighbouring surface of the crown of the tooth, otherwise food would be liable to lodge in the angle, and so recommence decay at the edge of the filling. This unfortunate occurrence is the cause, I feel sure, of the large majority of failures in fillings, and if the cause of caries were only definitely kept before the mind of the operator, this very common cause of failure would seldom, if ever, be met with.

Some operators recognise that in interstitial cavities the fillings must be constructed so that food will not lodge at the junction of the enamel and the filling. They admit, in fact, that it is the lodging of the food which in this situation gives rise to the decay, and a little careful observation will show them that certain foods lodge on the crowns of the teeth also, and that no tooth decays without the lodgment of food; further, that if a tooth commence to decay at the edge of the filling it is because the filling has been inserted in such a manner as to allow of food lodging. This latter condition is almost invariably preventible.

When the approximal surfaces of a tooth require to be filled it is almost always necessary to contour the teeth, not only to prevent the lodging of food at the edge of the filling, but also to prevent change of position of the teeth. This is often neglected, and the teeth

change their position by approximating each other; their normal relative position to the neighbouring teeth is disturbed, a form of irregularity is produced; food lodges in the new spaces formed and decay is set up, not only on the approximal sides of the teeth which are filled, but also on the remoter teeth whose position may have changed. Thus, then, it will be seen that a few bad interstitial fillings may predispose ultimately to a succession of carious cavities. It is important, too, to recognise the cause of caries from another point of view. It sometimes happens that the removal of a particular piece of partly decayed dentine may, for some reason or other, be inadvisable. We must, for example, recognise that we want to do the maximum amount of good with the minimum amount of pain, and whether we may leave a particular part of partly decayed dentine will depend on whether food and micro-organisms can lodge in the space or not. If food would not lodge at the particular spot if the dentine were left, then it may be left; if otherwise, it must be removed.

Another point of importance which will be useful if we are to give our patients the miminium pain: When the decay is rapid, that is when the kind of food eaten is liable to lodge and undergo rapid fermentation, as so frequently is the case with children's food, if the diet cannot be altered, then the tooth must be cut away much more freely from any spot where the food might lodge. On the other hand, when the decay is very slow the removal of the decay and proper shaping of the cavity and edges of the filling will be all that is required.

There is little connected with dental surgery and pathology which may be considered settled with scientific accuracy, and my attitude to current ideas and methods has led me to doubt if even the time-honoured method of cleaning the teeth with tooth-brush and powder can be advocated without considering that it may possibly be harmful. We are aware that mouths which have never felt a tooth-brush may occasionally be seen in which the teeth are all perfectly sound, and that at least equally frequently people who are scrupulously particular in the use of the tooth-brush have every tooth excepting the lower front teeth decayed and stopped in two or more places. Nor is this all. It frequently happens that the gums recede very rapidly in the mouths of those who use the tooth-brush most, and among this class too that painful and troublesome condition of erosion takes place at the neck of the teeth with or without recession of the gums or caries following.

Before stating the effect of the use of the tooth-brush let us consider Nature's methods of preserving the enamel. First, it may be preserved by being kept perfectly free from adherent matter as occurs on the crown surfaces of the teeth of those who eat coarse and non-lodgeable food-stuffs. Secondly, a protective layer of matter which does not become acid in reaction under normal circumstances may be deposited on the surface of the enamel and protect it from injury. Although this latter method is not recognised, I believe it is one which is utilised by nature, and is perhaps the only possible and satisfactory method at certain situations on the teeth. Hitherto this coating

has received little attention. It has been considered as merely so much deposit from the mucus of the saliva in a vitiated condition, or from other sources, and it is assumed that this ought to be got rid of by the aid of the tooth-brush as quickly as possible. I intend, however, to point out that this coating on certain parts of the teeth may be considered physiological, and only becomes pathological under certain conditions.

Let us now consider the nature and source of this coating.* There is reason to believe that its basis is buccal and salivary mucus. This is described as a viscid albuminous material containing albuminous mucous corpuscles frequently mixed with salivary epithelium and *débris*. In the situations where it adheres to the enamel of the teeth, and is not removed during mastication or by the tooth-brush, it may be felt by the tongue as a very slightly rough coating. It presents a different feeling to the tongue than does the polished enamel. It is frequently discoloured either from chromogenic micro-organisms or the pigments in the food, or from tobacco. From its albuminous nature and its being infected with micro-organisms it undergoes slow change. Its reaction on the surface of the teeth in the mouth is (as far as my testing with litmus shows) practically neutral. This reaction comes about presumably from the albuminous

* The data from which the following opinions have been derived were experiments chiefly carried out on one mouth. They have been confirmed by observations on others. There is no reason to consider that the mouth specially under consideration was in any way abnormal. It was selected simply because it was continuously under the writer's personal observation.

nature of the buccal mucus and corpuscles and salivary epithelium.

Although there are micro-organisms which infest this coating when no carbohydrates are mixed with or adhere to it in quantity, acid is not produced, at least in any quantity. Moreover, on account of the thinness of the coating, even if a small amount of acid is at times produced, it is neutralised by the saliva. I have found that in the morning, even after having eaten sweets on the previous evening, this coating is neutral in reaction.

The conclusion that this coating is normally of a neutral reaction is indicated by the fact that tartar is deposited in it in certain situations, *e.g.*, round the necks of the teeth, with almost equal frequency as the decalcification of the enamel in similar situations. The cause of both decalcification and the deposit of tartar is similar—viz., the elimination of the coarse and fibrous matter from the food-stuffs and the lodging in quantity of food at the places referred to. In the one case, however, the reaction given rise to as the joint result of saliva, buccal secretions, and food, is acid (carbohydrates being in excess), in the other it is alkaline (albuminous matter being in excess).

When a tooth-brush is frequently used the protective coating is brushed away from the necks of the teeth, and if lodgeable amylaceous or saccharine food is then eaten, the coating having been brushed away, the starchy matter lodges close to the necks of the teeth and the intensity of the acid formation is greater in close proximity to the enamel than it would have been had it been protected by a layer of albuminous mucus and corpuscles.

I think, moreover, there is perhaps even greater evidence which goes to show that this albuminous coating protects the necks of the teeth from the eroding action of the buccal mucous membrane or its secretions which are or become acid, and lodge in the triangle formed by the enamel, the edge of the gum, and the buccal mucous membrane. Assuming this to be true, we have another reason why the tooth-brush should not be used except for the coronal surfaces of the tooth when erosion exists at the neck of the teeth.

Thus, then, it appears that the tooth-brush is not an unmixed blessing, but nevertheless until the ordinary food consumed is changed or has its fibrous element restored, perhaps the tooth-brush may be usefully advocated at least for brushing the coronal surfaces of the teeth.

With regard to antiseptic mouth washes, they too are not without their objectionable features. Beneficial they may be in exceptional circumstances, but under normal conditions their use is, I believe, to be deprecated.

The mouth has never in the history of man or animal been an aseptic chamber, and paradoxical as it may seem, and contrary to all recent ideas relative to methods for the combating of caries, I will affirm that under proper dietetic conditions the bacteria of the mouth are valuable agents in the preservation of the teeth. The mouth bacteria give rise to the continual disintegration and removal of the protective mucous coating supplied by the buccal secretions. It is difficult to imagine a better method for the prevention of caries at those places where the friction of fibrous food cannot dislodge all adherent matter, for

while the mucous coating protects the necks of the teeth the bacteria provide a means for the removal of all accumulations of *débris*, whether it be decomposing food or incipient tartar deposit.

I need not insist upon how important it is that a method should obtain preserving the teeth from destruction by acid on the one hand and from the deposit of tartar on the other. Nor has any artificial method been suggested which arrives at this result so satisfactorily as is provided for by the means indicated, provided only that the food is sufficiently coarse and fibrous to ensure a fair amount of friction, a small amount of lodging food particles, and a sufficient amount of stimulus for the physiological uses of the teeth.

Now let us consider the objects aimed at and the methods advocated in text-books on dental surgery. The object is to free the buccal cavity from micro-organisms and the mucous, albuminous, and other matters which cling about the teeth. For this purpose the tooth-pick, floss silk, the tooth-brush, tooth-powders, tooth-soaps, and antiseptic mouth washes are advocated to be persisted in with irksome regularity and at inconvenient times. If the aim were achieved the very means for the natural method of preservation of the teeth would be destroyed. Fortunately the methods employed are so ludicrous, inefficient, and seldom performed that the total amount of good or harm resulting is relatively small.

We hear much of the great advances in dental surgery during the last thirty years, but unfortunately the advance

is not in the most desirable direction, for though the art has reached a great degree of perfection, and the instruments and mechanical means to ends show the most plausible ingenuity, still decay in teeth, irregularity, recession of the gums, and other dental diseases are increasing with marked rapidity. So long as the attention of dentists is absorbed in the art of filling and making teeth, so long as we are ignorant of the causes of the diseases we attempt to combat, even so long will dental surgery be merely an empirical art, and the suffering of mankind from dental decay and its consequences will go on apace. On the other hand, I maintain I have shown that there is the strongest evidence for believing that it is the food-stuffs which are the cause of caries, and that the weight of the authority of biological science strongly supports this view. If we devote our attention to the causes of dental caries there is every reason for hoping that our services as dental surgeons may be almost wholly unnecessary, and that we may devote our energies to productive labour instead of living, as it were, on the infirmities and suffering of our fellow men.

APPENDIX

EXPERIMENTAL DEMONSTRATION OF THE CAUSE OF THE EARLY DECAY OF TEETH

Some time ago you kindly published a series of articles on "The Etiology of Dental Caries," in which I put forward the view that "the cause of the prevalence of dental caries is that the natural food-stuffs are to a large extent ridded of their accompanying fibrous parts, and prepared and consumed in a manner which renders them liable to lodge and undergo acid fermentation in the mouth; while from the same cause, and the induced conditions, the micro-organisms of the mouth lodge and multiply, and augment the rapidity and intensity of the acid fermentation."

It was after what, to my mind, was proof positive that I wrote the articles, and fortunately the arguments then brought forward have convinced many and partially convinced others. I was persuaded, however, that no amount of argument would convince many who believed in the hereditary and constitutional nature of the disease, nor those who were confirmed in the belief that the teeth of civilised man had become degenerate.

If the theory I put forward were true, it occurred to me that the teeth of many of the lower animals might probably be no more immune to caries than are the teeth of men. I

came to the conclusion that the freedom was due almost solely to dietetic causes. In order to test this I bought a monkey and tried to put it on a diet from which all coarse and fibrous matter had been removed, such as fine biscuits, toast, bread and milk, chocolate, cheese, meat juice, &c. At first I had provided the monkey with a bed of hay, and after it had satisfied itself with biscuits and milk it immediately commenced chewing the hay. This, of course, spoiled the experiment, so I removed the hay, but as the weather was cold I supplied the monkey with a little box lined with cork. Unfortunately, again it took to chewing the cork between meals. I next removed the cork and box, as I thought it would be better to let it sleep on the bare floor of the cage than have it chewing fibrous material for a considerable part of the day. Still, however, it did not understand the nature of my experiment, and persisted in nibbling off little pieces of wood from the sides of the wooden cage and running about with them in its mouth. I then rubbed the cage with quinine at all places which were accessible to the teeth or hands of the monkey, and it gradually gave up the habit of chewing these little pieces of wood. I mention these facts, not to amuse the reader, but to show how this animal and, I presume, other monkeys, preserve their so-called "immunity" to dental caries.

The diet which the monkey received from this time onwards consisted almost wholly of fine biscuits, toast, bread and milk, and milk. It also had frequently a little treacle (one pound in all during about six months). Occasionally it had milk pudding, and, perhaps about a

dozen times, potatoes and milk; it had also a little chocolate, about two or three ozs. in all, and about thirty lumps of loaf sugar.

At the end of the first four months I examined its teeth carefully, but although I thought there seemed to be slight indications of caries on the symphysial side of the first left lower molar, I thought it better to wait for more positive signs, and so did not trouble to examine the teeth for six months. On this second examination I found in the two upper first molars (which were the hind-most teeth in this monkey's head, as the animal was young and the other molars had not yet erupted) tiny discoloured crevices between the anterior and posterior interior cusps, which seemed very much like caries. I extracted these two upper molar teeth and ground them down in order to see the suspicious spots under the microscope, with the following result:—

Upper right molar. The crevice was found to be more than half the depth of the enamel, and around the deepest part of the crevice the enamel to the naked eye showed a chalky appearance. The margin of the crevice appeared stained brownish yellow under the microscope. From the bottom of the crevice there descended, nearly to the dentine, a strand of apparently disintegrating enamel. The dentine beneath this enamel was translucent, the translucency penetrating the dentine more than half-way to the pulp. The edges of the crevice were somewhat rough and cracks penetrated it.

A few days later, after the animal died, I examined the left lower molar. It showed on section, under the micro-

scope, the enamel completely removed at one spot down to the dentine. The dentinal tubules immediately below the denuded part were swollen and granular, and some apparently filled with micro-organisms. I may mention that a transparent cone of dentine reached from the disintegrated enamel to the pulp, when the section was examined before mounting in Canada balsam. Both of these teeth, therefore, presented appearances, at least, strongly simulating incipient dental caries.

The upper left molar, though discoloured in the crevice, showed no sign of caries.

It will be seen that the caries had not extended very far, but it must be remembered that the animal started with a set of teeth which were very actively used, so regular, so well polished, so small, and so protected by the gum coming up over the enamel, that I almost doubted whether I should see caries in its teeth at all unless it lived a very considerable time. I may state that it seemed in my opinion next to impossible for almost any teeth in this monkey's head to decay, as the natural fissures—for example, in the premolars—had been completely worn out, and a beautifully polished smooth surface was left on which food could hardly by any possibility lodge, and as I have just mentioned, the gums overlapped the enamel and came up between the teeth in a manner which seemed very perfectly adapted for preventing caries. I hoped for recession of the gums to take place under the diet, or that the more posterior molars should, on coming into position, be more liable to lodge food. Fortunately the crevices in the first molars were sufficient, and if the amount of caries

observed was brought about in, say nine months, what sort of state would these molars be in at the end of five years? I suppose pretty much the same state as are the first molars of children who are fed on the most "approved" principles, five years after their eruption.

It may be asked why I did not let the experiment go on longer before writing about it. Unfortunately the experiment came to a sudden end on account of a heating apparatus giving rise to a fire, which suffocated the monkey. Still, the nine months have, I think, just been sufficient. Perhaps some other investigator will be more fortunate and continue the experiment for four or five years as ought to have been done.

The liability to caries, therefore, appears to be almost solely due to the fact that the food-stuffs are refined and administered in a form which is very much more liable to lodge in the natural crevices of the teeth, and there is practically no need for the assumption that the liability to caries has been brought about by any hereditary degeneration of the teeth, nor by any molecular structural alteration due to defective nutrition of the teeth, nor by any supposed vitiation of the buccal secretions, nor by any constitutional states of the system brought about by indigestion, nor by any other of the multitudinous suppositions which have been advanced from time to time.

I have advanced arguments elsewhere,* not only from my own observations, but from the accumulated mass of facts which have been heaped up for years; unfortunately, however, arguments which necessarily involve close following

* "Cause and Prevention of Decay in Teeth."

and an abandonment of many current prejudices do not convince every one. Very many of the same facts have in other theories been continually misinterpreted, mainly, I believe, from the persistent habit of looking to the teeth and not to the food for the explanation, and from the almost universal belief that the disease is inherited. If it is supposed that the disease is inherited, then of course the causes which lead up to it would require to be sought for throughthe constitution. Hence has resulted the fact that some recent observers,* having seen the futility (after chemical and microscopical examination of the teeth) of seeking the cause of susceptibility to caries in the teeth themselves, have found it necessary to seek it through the oral secretions.

I may state that I endeavoured to ensure that the food should be in no way deficient in nutritive value lest it might be said that the teeth became predisposed or less resistant to caries through defective nutrition of the tooth.

It should also be noted that the food was of such a quality that the jaws were required to be exercised, *e.g.*, biscuits, toast, loaf sugar, so that if it be said that "the pressure brought to bear upon the teeth by mastication causes a more lively circulation in the periosteum and in the pulp, thereby inducing an increased deposit of lime salts or a more complete calcification,"† then this method of securing immunity was not disregarded. And I think it could not be said that the soft quality of the food this animal had previously consumed had brought about "a soft porous dental substance."‡

* Black, "Susceptibility and Immunity to Dental Caries."

† Millar, "Micro-organisms of the Human Mouth."

‡ Millar, *ibid.*

I mention this, as it is important (from the point of view of prevention) to differentiate between the dietetic theories which trace the predisposition through the supposed nutritional changes in the teeth and the theory which I put forward tracing the prevalence of caries to the relative lodgeability of the food-stuffs.

The experiment just recorded was not carried out with as much precision as it deserved. Unfortunately during the greater part of the time I was prevented by illness from giving it my personal attention. The experiment, too, was merely a preliminary one, and as I have said, was prematurely ended. Still I trust that the recording of this experiment, abortive though it may be, may prevent it being said again that the reason for the immunity to dental caries in animals has still to be discovered, or that the cause of the early decay of teeth is still unknown. Until at least some similar experiment, more thoroughly carried out, negatives the inferences I have made, we may be justified in believing that " the cause of the prevalence of dental caries is that the natural food-stuffs are to a large extent ridded of their accompanying fibrous parts, &c." *

* Were I to perform such an experiment again I should not allow toast. As far as I can discover from clinical evidence it does not seem to be harmful. Probably toast is sufficiently coarse to dislodge the micro-organisms where they usually lodge and multiply.

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